Rogers

United States
Department of
Agriculture
Forest
Service
Southwestern
Region

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Forest Pest Management Report

R-3 84-11

WESTERN SPRUCE BUDWORM DAMAGE
ASSESSMENT PROJECT

Carson National Forest
New Mexico

Progress Report No. 5

May 1984

3430

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By

T. J. Rogers

MAY 23 1984

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USDA Forest Service, Southwestern Region
State and Private Forestry
Forest Pest Management
517 Gold Avenue, SW
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INTRODUCTION

The western spruce budworm (WSBW), Choristoneura occidentalis Free., has been a cyclic pest of mixed conifer stands in the Southwest ever since records were first kept in the early 1920's. Since then, four outbreaks have occurred and a fifth is currently in progress.

During the earlier four outbreaks recorded in the Southwest (1920's, 1930's, 1940's, and 1950's), information obtained was primarily limited to (1) general area(s) of infestation, (2) duration of the outbreak, and (3) occasionally, severity of defoliation. However, quantitative information concerning top-kill damages, growth loss, and mortality was never collected.

Because of the need for this information for deciding whether or not pest management is warranted, a long-term damage assessment project was initiated on the Carson National Forest in 1978. This is the fifth of a series of reports documenting the establishment of the project and the damages occurring from the current WSBW outbreak. Other reports issued include those by Holland and Lessard 1978; Stein 1979 and 1980; Stein and McDonnell 1981.

OBJECTIVES

The purpose of this report is to update the damages occurring to Douglas-fir, true fir, and spruce resulting from the current WSBW outbreak on the Carson National Forest, New Mexico. Specific objectives of this report are to:

1. Present the data obtained on growth loss for the past infestations occurring from 1922 to 1966 and the current infestation which began in 1975.

2. Summarize the data obtained on egg mass and larval densities from 1978 through 1983 and relate these population indices to subsequent defoliation and tree damages observed.

3. Summarize the effects of site class on overall defoliation and tree damages.

4. Summarize the cumulative top-kill damages and mortality to pole- and sawtimber-sized trees resulting from WSBW defoliation as of 1982.

METHODS

Block Establishment

Twelve 1-acre blocks were permanently established in June 1978: Nine blocks were located in drainages of the Rio Fernando de Taos on the Taos Ranger District (Capulin Canyon, Garcia Park, La Jara Canyon, and

Palo Flechado Pass) and three blocks in the Cabresto Creek drainage on the Questa Ranger District (figures 2-6, appendix A). Little or no defoliation had occurred on these blocks prior to their establishment. First aerial detection of defoliation in the vicinity of the blocks was as follows: Capulin Canyon and Garcia Park, 1976; La Jara Canyon, Palo Flechado Pass, and Cabresto Canyon (blocks 11 and 12), 1977; and Cabresto Canyon (block 9), 1978.

In 1979, five additional blocks were established to serve as check blocks: Four blocks (Nos. 13-16) near Osha Mountain on the Taos Ranger District and one block (No. 17) near Burned Mountain on the Tres Piedras Ranger District (figures 7 and 8, appendix A). However, budworm populations were found on the Osha Mountain blocks in 1979 and on the Burned Mountain block in 1980. Defoliation was first detected aerially on Osha Mountain in 1981 and on Burned Mountain in 1983.

Dwarf mistletoe is widespread in Douglas-fir stands on the Carson National Forest. But, because it causes some tree damages similar to those resulting from budworm defoliation, mistletoe's presence on study blocks would make it difficult to analyze damages due to budworm. For this reason, most of the damage assessment blocks were established in stands with little or no mistletoe. However, half of block 7 and most of block 14 are heavily infected with dwarf mistletoe. Data from these two areas may indicate whether or not heavier tree damages result when mistletoe and budworm are both present.

All blocks were permanently marked using paint and flagging, witness trees, and corner stakes. Blocks were located to provide a representative sample of three site classes and the past infestations. Three Douglas-fir site trees were measured on each block to determine site index. Site class codes were determined from site index values as follows:

Site class code	
I	site index 75 or above
II	site index 55-74
III	site index 54 or below

When each block was initially established, all confiers (including nonhost species) with a d.b.h. of 5 inches or greater were permanently tagged with block and tree numbers. Trees with a d.b.h. of 5.0 to 8.9 inches were classed as poles, while those with a d.b.h. of 9.0 inches or larger were classed as sawtimber. The following information was obtained from each tree:

1. Species
2. Height (to nearest foot)
3. D.b.h. (to nearest 0.1 inch)
4. Amount of top-kill (length to nearest foot)
5. Condition (live or dead)
6. Crown ratio

In 1982 and 1983, the above information for each tree on each block, including site class and cumulative damages as of 1982, was compiled into computer subfiles to be used with the SPSS (statistical package for the social sciences) programs, an integrated system of computer programs designed for the analysis of social science data. The subfiles were then cross tabulated to generate many of the tables presented in the appendixes. These subfiles and the runstream are archived at the Fort Collins Computer Center.

In addition, a tally was made in 1981 of all pole- and sawtimber-sized aspen present on the blocks. However, these trees were not permanently tagged.

Damage Assessment

1. Defoliation. On each block, 25 Douglas-fir trees, 20 to 40 feet in height, were selected for sampling defoliation in 1978 through 1983. To reduce the effect of sampling on individual trees, only 10 of the 25 were to be sampled each year (i.e., 1978, trees 1-10; 1979, trees 11-20; 1980, trees 21-25 and 1-5; etc.). In 1983, the number of trees sampled was further reduced from 10 to 5 trees. The method used to estimate budworm defoliation in 1982 and 1983 was the "six-class system."[1] This method involved sampling two apical branches: A branch (70 cm in length) from opposite sides at midcrown of each sample tree. On each branch sample, 25 new shoots were examined for current defoliation using the left side of one branch and the right side of another, and so on. Each new shoot was individually examined for defoliation and assigned an index and midpoint value as follows:

Defoliation class %	Index value	Midpoint value
0	0	0
1-25	1	12.5
26-50	2	37.5
51-75	3	62.5
76-99	4	87.5
100	5	100

After index values were determined for the branch samples, individual tree defoliation was calculated using the following formula:

$$\% \text{ defoliation} = \frac{(n_1)(12.5) + (n_2)(37.5) + (n_3)(62.5) + (n_4)(87.5) + (n_5^2)(100)}{100}$$

Where n_1 = number of twiglets with index value 1
n_2 = number of twiglets with index value 2
n_3 = number of twiglets with index value 3
n_4 = number of twiglets with index value 4
n_5 = number of twiglets with index value 5

[1]Parker, D. L., R. E. Acciavatti, and E. D. Lessard. 1978. Western spruce budworm suppression and evaluation project using carbaryl, 1977. Progress Rep. No. 1. R-3 78-11. 136 pp.

In the 6-class system, block defoliation was simply the average of the individual tree values.

2. Growth Loss. A major objective of the project is the evaluation of radial growth loss which resulted from past infestations that occurred from 1922-1966, and the current infestation which began in 1975. Work on this objective began with the collection of increment cores in 1978 and 1979. On each block, 2 cores, 90° apart, were taken at d.b.h. from each of 30 sample trees: 10 Douglas-fir, 10 true fir, and 10 ponderosa pine. The core samples were placed in plastic straws for storage, labeled for identification, and sent to the Intermountain Forest and Range Experiment Station, Moscow, Idaho, where radial growth measurements were done on an Addo System.

However, major problems appeared when core data were prepared for a tree-ring analysis computer program. Consultation with the Modern Studies Unit of the University of Arizona's Laboratory of Tree-Ring Research (the world center for dendrochronology) revealed that problems encountered could have been avoided if sufficient information on dendrochronology had been obtained prior to core collection and measurement.

The data obtained from core collected in 1978 and 1979 could not be used to analyze past infestations. The primary reason was that the cores were not cross-dated[2] prior to measurement. In many instances, the two cores from the same tree contained a different number of rings. The differences were a result of two things: Cores were taken off center and/or they had one or more missing rings. Because cores were stored in plastic, they became rotten and could not be reexamined for cross-dating.

In order to meet the growth loss objective, new cores were collected in 1982 to analyze the effects of past infestations, as well as those of the current infestation, by personnel from the Laboratory of Tree-Ring Research. The methods used to obtain this information are described in the report in appendix D.

3. Top-kill and Tree Mortality. In the year of block establishment, all pole- and sawtimber-sized trees were examined for top-kill and tree mortality; the length of each dead top was estimated to the nearest half foot. All top-kill and tree mortality not attributed to the current infestation were documented as base line data. All top-kill and tree mortality resulting from the current budworm infestation are presented in the appropriate appendixes and tables.

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[2]Cross-dating is the basic technique of modern dendrochronology and, through systematic comparison of tree-ring patterns, it allows the determination of tree-ring dates which are accurate to the year.

All trees were examined in midsummer for top-kill and mortality. In addition to this midsummer examination, another tree condition survey was conducted in May at about the time of bud flush and prior to heavy budworm feeding to verify earlier observations. Verification is necessary because it is often difficult to determine top-kill from a single observation due to the tree's ability to establish adventicious buds and refoliate after intense defoliation. Sometimes, a tree's top will be completely defoliated for several consecutive years, with refoliation occurring each year. Only "top-kill" on which no live buds were observed was recorded.

In 1980 and 1981, blocks were examined by a pathologist to determine if any pathogens were present which could produce or contribute to the occurrence of top-kill and tree mortality. Also, in 1981 (and planned for remaining years of the project), all dead and dying trees were examined to determine if pathogens contributed to or were the primary cause of mortality.

Insect Densities

On each block, 25 Douglas-fir trees, 20 to 40 in height, were selected for sampling insect densities. To reduce the effect of sampling on individual trees, only 10 of the 25 were to be sampled each year. These sample trees were the same as those selected for defoliation sampling.

1. Egg Masses. Egg masses were sampled by cutting two 70-cm midcrown branches from opposite sides of each sample tree with a pole pruner. The length and width of branches were measured to calculate foliated branch surface area. Each branch was then individually bagged in a ¼-bushel paper or cloth sack, transported to the laboratory, and stored at about 40° F prior to examination.

Foliage was examined under ultraviolet light for egg masses. Needles bearing egg masses were classed as from current year's foliage or a previous year's and kept separate in labeled pill boxes. New egg masses, deposited in the year of sampling, were separated under a stereomicroscope from old egg masses deposited in the previous year(s). All egg masses on current year's foliage were classed as new and their characteristics formed the basis for aging those egg masses found on a previous year's foliage.

2. Larvae. Sampling was begun when 20 percent of the larvae were in the fifth instar or larger. On each tree, two 15-inch branches were cut from opposite sides of the midcrown using a pole pruner with attached collecting bag. If a sample branch did not have at least 15 live buds, another branch was cut. The length and width of branches were recorded to determine the foliated branch surface area.

Larvae were removed from sample branches, counted, and preserved in ethyl alcohol. Total numbers of larvae and live buds per branch were recorded. Head capsule measurements were taken on a 25-percent subsample to determine instar distribution at time of sampling.

RESULTS AND DISCUSSION

Stocking and Species Composition

Stocking and species composition on blocks 1 through 12, 13 through 16, and block 17 were not much different than they were at the time of block establishment in 1978 and 1979, respectively. Poles generally outnumbered sawtimber, and Douglas-fir was the predominant host species on most blocks. These data are summarized in tables 1 through 9, appendix B.

Damage Assessment

In the following discussions, the loss assessment sample blocks have been divided into three groups based on the time of initial infestation period; i.e., blocks 1 through 12 (1978); blocks 13 through 16 (1979); and block 17 (1980).

1. Defoliation

Blocks 1 Through 12. WSBW defoliation on blocks 1 through 12 (table 10, appendix C) was first observed in 1978 at which time 52.5 percent of the new foliage growth was defoliated. Average defoliation on these blocks increased in 1979, 1980, and 1981 to 81.7, 82.9, and 85.6 percent and then decreased to 48.3 and 27.6 percent in 1982 and 1983, respectively.

When defoliation data for blocks 1 through 12 were grouped by site class, no consistent pattern of defoliation was observed for a particular site class. Defoliation by site class is summarized for these blocks below:

		Percent defoliation					
Site class	n	1978	1979	1980	1981	1982	1983
I	5	56.1	66.6	84.5	76.6	72.7	41.0
II	4	64.0	89.8	81.3	91.2	33.4	27.7
III	3	38.8	76.2	82.5	93.2	27.6	26.9

Differences in cumulative and average yearly defoliation percentages (summarized below) were also negligible; however, cumulative and average yearly defoliation was somewhat higher on site classes I and II.

Site class	n	Cumulative defoliation (1978-1983) %	Average defoliation (1978-1983) %
I	5	393.0	65.5
II	4	387.4	64.6
III	3	345.2	57.5

Blocks 13 Through 16. Defoliation on blocks 13 through 16 was first detected in 1979. Average defoliation on these blocks more than tripled each year from 1979 to 1981; i.e., from 7.8 percent in

1979 to 26.1 percent in 1980, and 91.8 percent in 1981. Defoliation in 1982 and 1983 then decreased significantly to 63.0 and 28.4 percent, respectively (table 10, appendix C). With the exception of the 1982 data, defoliation was consistently higher on site class II blocks. These data are summarized below:

		Percent defoliation				
Site class	n	1979	1980	1981	1982	1983
I	1	1.4	1.8	75.5	80.4	13.6
II	3	10.0	34.1	97.2	57.2	33.3

Cumulative and average yearly defoliation percentages for blocks 13 through 16 are summarized below:

Site class	n	Cumulative defoliation (1979-1983) %	Average defoliation (1979-1983) %
I	1	172.7	34.5
II	3	235.3	47.1

Block 17. Defoliation was first detected on block 17 (table 10, appendix C) in 1980. Budworm defoliation on this block has been light, averaging only 25.7, 27.5, 56.6, and 17.3 in 1980, 1981, 1982, and 1983, respectively. For the period 1980 to 1983, the cumulative defoliation percent and the average defoliation percent for this site class II block were 129.1 and 32.3 percent, respectively.

2. Growth Loss

The results of this portion of the project (appendix D) are discussed in the report prepared by: Thomas W. Swetnam, Laboratory of Tree-Ring Research, Modern Studies Section, University of Arizona, Tucson, Arizona 85721.

3. Top-kill and Tree Mortality

In the following discussions and related tables, top-kill is either classified as apparent or confirmed. Apparent top-kill includes those trees with 6 inches or less of complete defoliation (bare tops), but which are still alive and capable of refoliation through adventicious budding. Trees which have failed to refoliate after three consecutive years and with 6 inches or more of top-kill were classified as confirmed top-kill. In addition, confirmed top-kill and tree mortality data are cumulative; i.e., 1982 top-kill and mortality includes trees damaged and killed in 1978, 1979, 1980, and 1981. Trees were last reexamined in 1982 and are not scheduled for reexamination until the summer of 1987 or when the current outbreak collapses. Only cumulative pole and sawtimber damages are presented and discussed in this report.

An examination of the top-kill damage data (tables 11 through 19, appendix E) for poles and sawtimber shows that similar

damage trends occurred in both size classes and that poles continued to sustain a higher level of damage than sawtimber-sized trees. Apparent top-kill damages were observed on all 17 blocks examined, while confirmed top-kill damages occurred on sample blocks 1 through 12 and block 13. Both apparent and confirmed top-kill damages for individual blocks were highly variable. Top-kill damages for blocks 1 through 12, 13 through 16, and block 17 are discussed and summarized below.

Blocks 1 Through 12. On blocks 1 through 12, which became infested with budworm in 1978, 47.1 percent of the host type reexamined (1,550 trees) were top damaged. Of these, 22.6 percent were classified as apparent top-kill and 24.5 percent as confirmed top-kill. Apparent top-kill damages to pole and sawtimber amounted to 26.8 and 15.6 percent, while confirmed top-kill damages amounted to 29.1 and 16.8 percent of the total poles and sawtimber examined. Both apparent and confirmed top-kill damages occurred predominantly on Douglas-fir, followed by white fir and spruce (tables 11 through 14, appendix E); these data are summarized by species and condition class below:

Poles	DF	WF	S	Total trees damages
Apparent top-kill (%)	74.8	12.0	13.2	258
Confirmed top-kill (%)	58.6	26.4	15.0	280
Sawtimber				
Apparent top-kill (%)	66.3	23.9	9.8	92
Confirmed top-kill (%)	59.6	27.3	13.1	99

When these top-kill damages are grouped by site class, confirmed top-kill damages appeared to be slightly higher on site class 1 and III blocks. Top-kill damages by site class are summarized below:

	Site class		
Top condition	I	II	III
Apparent top-kill (%)	34.1	16.7	16.2
Confirmed top-kill (%)	27.5	19.1	27.6
Total trees examined	539	553	458

Blocks 13 Through 16. Top-kill damages on blocks 13 through 16, which first became infested with budworm in 1979, were observed on 27.8 percent of the 803 host trees reexamined in 1982. Damages observed were categorized as follows: 26.7 percent apparent top-kill and 1.1 percent confirmed top-kill. Of the trees with confirmed top-kill, 1.5 percent were poles and less than 1 percent (0.4) were

sawtimber. Both apparent and confirmed top-kill damages predominantly occurred on Douglas-fir (tables 15 through 18, appendix E); these top-kill damages are summarized below:

Poles	DF	WF	TF	S	Total trees damaged
Apparent top-kill (%)	58.5	15.1	5.0	21.4	159
Confirmed top-kill (%)	100.0	0	0	0	8
Sawtimber					
Apparent top-kill (%)	70.9	18.2	5.5	5.5	55
Confirmed top-kill (%)	100.0	0	0	0	1

Blocks 13 through 16 were grouped into two site classes: Site class I, block 16; site class II, blocks 13, 14, and 15. Top-kill damages, both apparent and confirmed, were greater on the site class II blocks. These data are summarized below:

	Site class	
Top condition	I	II
Apparent top-kill (%)	10.8	37.0
Confirmed top-kill (%)	0	1.8
Total trees examined	316	487

Block 17. On block 17, where budworm was detected for the first time in 1980, 1.5 percent of the 202 host trees examined showed apparent top-kill damages; no confirmed top-kill damages were detected. Damages observed on this class II site were limited to pole-sized trees and consisted of one Douglas-fir, one white fir, and one spruce (table 19, appendix E).

No new mortality resulting from budworm defoliation was detected in 1982. Mortality to pole- and sawtimber-sized host trees was last reported in 1981 (Stein and McDonnell 1981), at which time 16 trees had died out of 1,626 trees examined. Observed mortality was predominantly higher on blocks 1 through 12 and consisted of 10 poles and 1 sawtimber-sized tree; mortality on blocks 13 through 16 consisted of 5 pole timber-sized trees. No mortality was observed on block 17.

Insect Densities

Block 1 Through 12. Average egg mass densities for blocks 1 through 12 have been monitored since 1978, at which time egg mass densities for these blocks averaged 20.6 egg masses per m^2 of foliage. The average egg mass densities for these blocks increased from 1979 through 1980 to 37.6 and 58.7 egg masses per m^2, respectively, and then decreased substantially in 1981 to 23.7 egg masses per m^2. In 1982 and 1983, the average egg mass densities for these blocks remained relatively unchanged, averaging 24.4 and 25.5, respectively. These data and those for each of the individual blocks sampled are summarized in table 20, appendix F.

WSBW larval densities for blocks 1 through 12 averaged 25.4, 16.5, 17.3, and 11.8 percent in 1979, 1980, 1981, and 1982, respectively. Larval densities from 1979 to 1981 resulted in similar amounts of defoliation: 82.3, 82.9, and 86.6 percent, respectively, and a reduced level of defoliation of 48.3 percent in 1982. These data, along with those for each of the individual blocks sampled, are summarized in table 21, appendix F.

Blocks 13 Through 16 and 17. Budworm egg mass densities and larval densities were first sampled on these blocks in 1979 (tables 20 and 21, appendix F). Egg mass densities for blocks 13 through 16, from 1979 through 1983, averaged 11.3, 16.4, 23.1, 13.4, and 27.8, while larval densities from 1979 through 1982 averaged 0.4, 4.9, 17.5, and 19.1, respectively. For block 17, during these same periods, egg mass densities averaged 0, 1.8, 8.5, 19.0, and 10.8, while larval densities averaged 0.4, 4.8, 17.5, and 9.0, respectively. Overall, WSBW infestation levels have been less severe on these blocks when compared to those of blocks 1 through 12 initially infested in 1978.

CONCLUSIONS

Top-kill damages, both apparent and confirmed, appear to be directly related to a combination of defoliation intensity and total number of years of consecutive defoliation. Top-kill damages were: Heaviest on blocks 1 through 12 where moderate to heavy defoliation has occurred for five consecutive years; moderate on blocks 13 through 16 where light to moderate defoliation has occurred for four consecutive years; and light on block 17 where light defoliation has occurred for three consecutive years. Poles generally sustained greater damages as did Douglas-fir on all blocks reexamined in 1982.

The effects of site class on defoliation and subsequent damages, although data are inconclusive, appear to be minor.

Comparisons of filtered host and nonhost tree-ring series (appendix D) clearly identified three periods of low growth at several sites sampled that corresponded with known periods of WSBW outbreaks. The maximum growth loss during a single year of the outbreaks was usually greater than 50 percent. Average growth loss during 5-year periods was approximately 30 to 40 percent. The maximum growth loss from one year to the next was generally greater than 50 percent and was as high as 100 percent. In general, the measures of growth loss sampled in most areas are conservative.

No new mortality to pole- and sawtimber-sized trees was detected in 1982. The mortality last observed in 1981 was probably due to a combination of several years of consecutive, severe defoliation and plant diseases such as root rots, rusts, and dwarf mistletoe.

In general, average egg mass densities correlated well with expected trends for defoliation. However, no consistent relationships could be found between average egg mass densities and average larval densities. Also, the relationships between average larval densities and expected defoliation were highly variable and inconclusive.

PLANS FOR FY 1984

Data will continue to be collected on defoliation and insect densities (egg masses) in 1984. However, data on top-kill damages and mortality will not be reexamined until FY 1987, at which time Progress Report No. 6 will be scheduled for distribution.

LITERATURE CITED

Holland, David G., and Gene Lessard. 1979. Western spruce budworm damage evaluation, 1978. Progress Rep. No. 1. R-3 79-11. 16 pp.

Stein, Catherine R. 1980. Western spruce budworm damage assessment project, 1979. Progress Rep. No. 2. R-3 80-5. 25 pp.

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Stein, Catherine R., and George R. McDonnell. 1982. Western spruce budworm damage assessment project, 1981. Progress Rep. No. 4. R-3 82-12. 40 pp.

LIST OF APPENDIXES

Appendix A: Location maps for loss assessment blocks 1 through 17

Appendix B: Stocking and species composition for blocks 1 through 12, 13 through 16, and 17.

Table 1: Trees species per acre vs. plot number, blocks 1 through 12. WSBW damage assesment project, Carson National Forest, New Mexico

Table 2: Tree category vs. plot number, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

Table 3: Summary of tree category vs. tree species, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

Table 4: Tree species per acre vs. plot number, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

Table 5: Tree category vs. plot number, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

Table 6: Summary of tree category vs. tree species, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

Table 7: Tree species per acre vs. plot number, block 17. WSBW damage assessment project, Carson National Forest, New Mexico

Table 8: Tree category vs. plot number, block 17. WSBW damage assessment project, Carson National Forest, New Mexico

Table 9: Summary of tree category vs. tree species, block 17. WSBW damage assessment project, Carson National Forest, New Mexico

Appendix C: Defoliation data: 1978-83

Table 10: Percent defoliation to Douglas-fir on 1-acre sample blocks, WSBW damage assessment project, Carson National Forest, New Mexico, 1978-83

Appendix D: Radial growth assessment of WSBW-infested Douglas-fir trees on the Carson National Forest, New Mexico

Appendix E: Pole and sawtimber top-kill damages for blocks 1 through 12, 13 through 16, and 17

Table 11: Host tree species per acre vs. plot number for apparent top-kill damages to pole timber, block 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

Table 12: Host tree species per acre vs. plot number for confirmed top-kill damages to pole timber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

Table 13: Host tree species per acre vs. plot number for apparent top-kill damages to sawtimber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

Table 14: Host tree species per acre vs. plot number for confirmed top-kill damages to sawtimber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

Table 15: Host tree species per acre vs. plot number for apparent top-kill damages to pole timber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

Table 16: Host tree species per acre vs. plot number for confirmed top-kill damages to pole timber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

Table 17: Host tree species per acre vs. plot number for apparent top-kill damages to sawtimber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

Table 18: Host tree species vs. plot number for confirmed top-kill damages to sawtimber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

Table 19: Host tree species vs. plot number for apparent top-kill damages to poletimber, block 17. WSBW damage assessment project, Carson National Forest, New Mexico

Appendix F: Insect density data summaries

Table 20: Average egg mass densities, WSBW damage assessment project, Carson National Forest, New Mexico, 1978-83

Table 21: Average larval densities, WSBW damage assessment project, Carson National Forest, New Mexico, 1979-82

APPENDIX A

Location maps for loss assessment
blocks 1 through 17

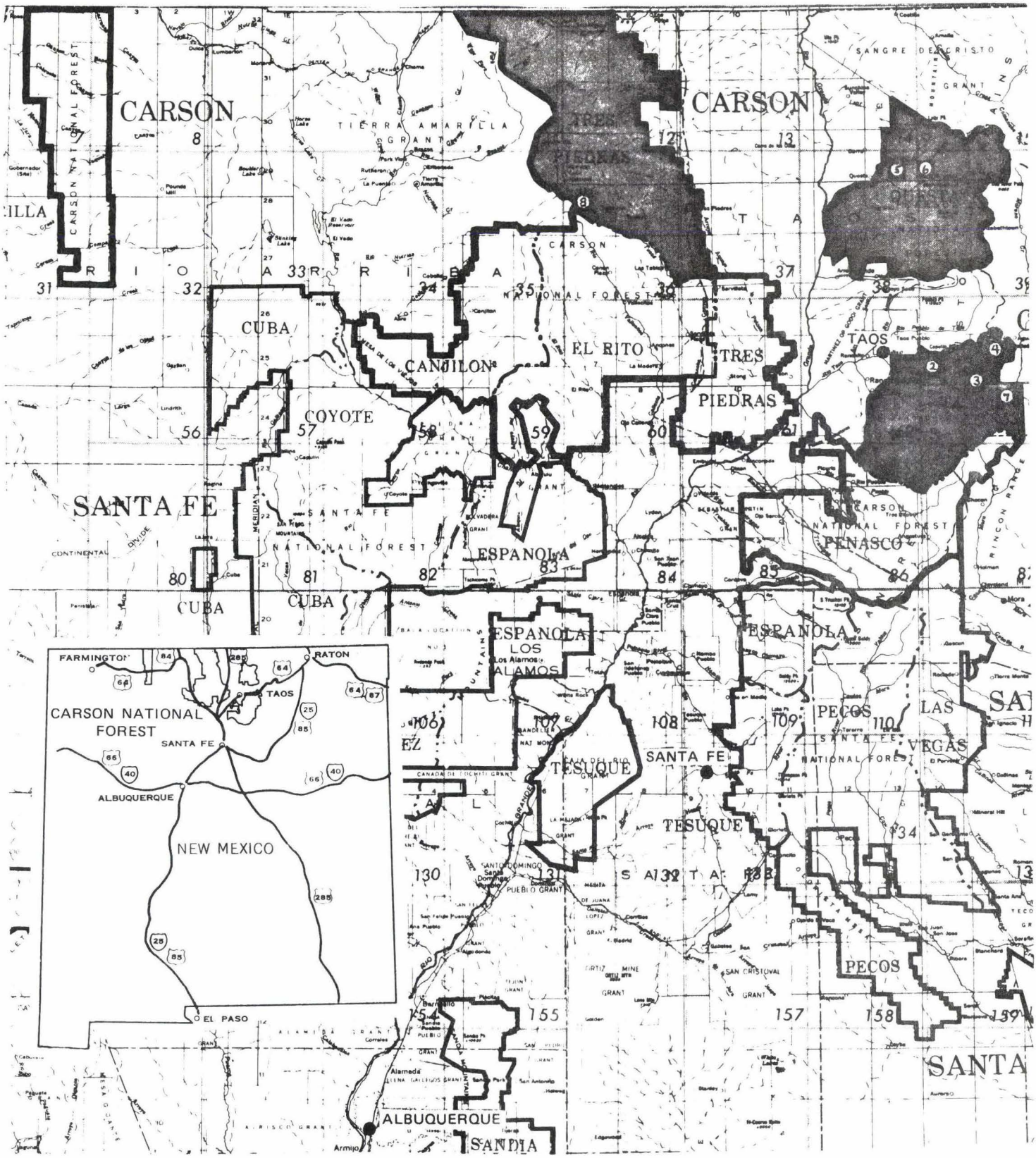

Figure 1. General location of evaluation blocks for the Spruce Budworm Damage Assessment Project on the Tres Piedras, Questa, and Taos Ranger Districts, Carson National Forest, 1978-81. Numbers (2 - 8) indicate subsequent maps (Figures 2-8) which show specific locations of 17 evaluation blocks.

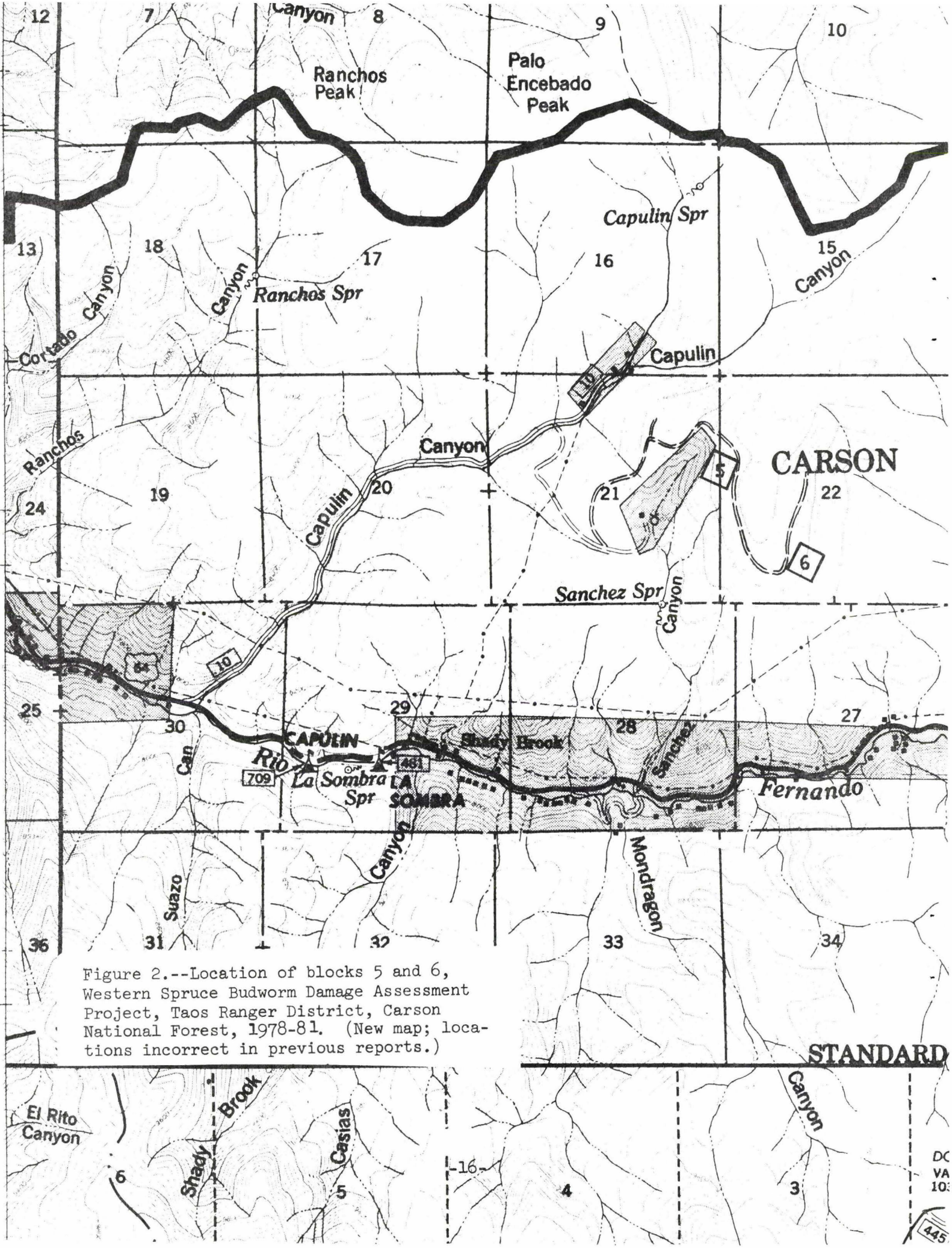

Figure 2.--Location of blocks 5 and 6, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1978-81. (New map; locations incorrect in previous reports.)

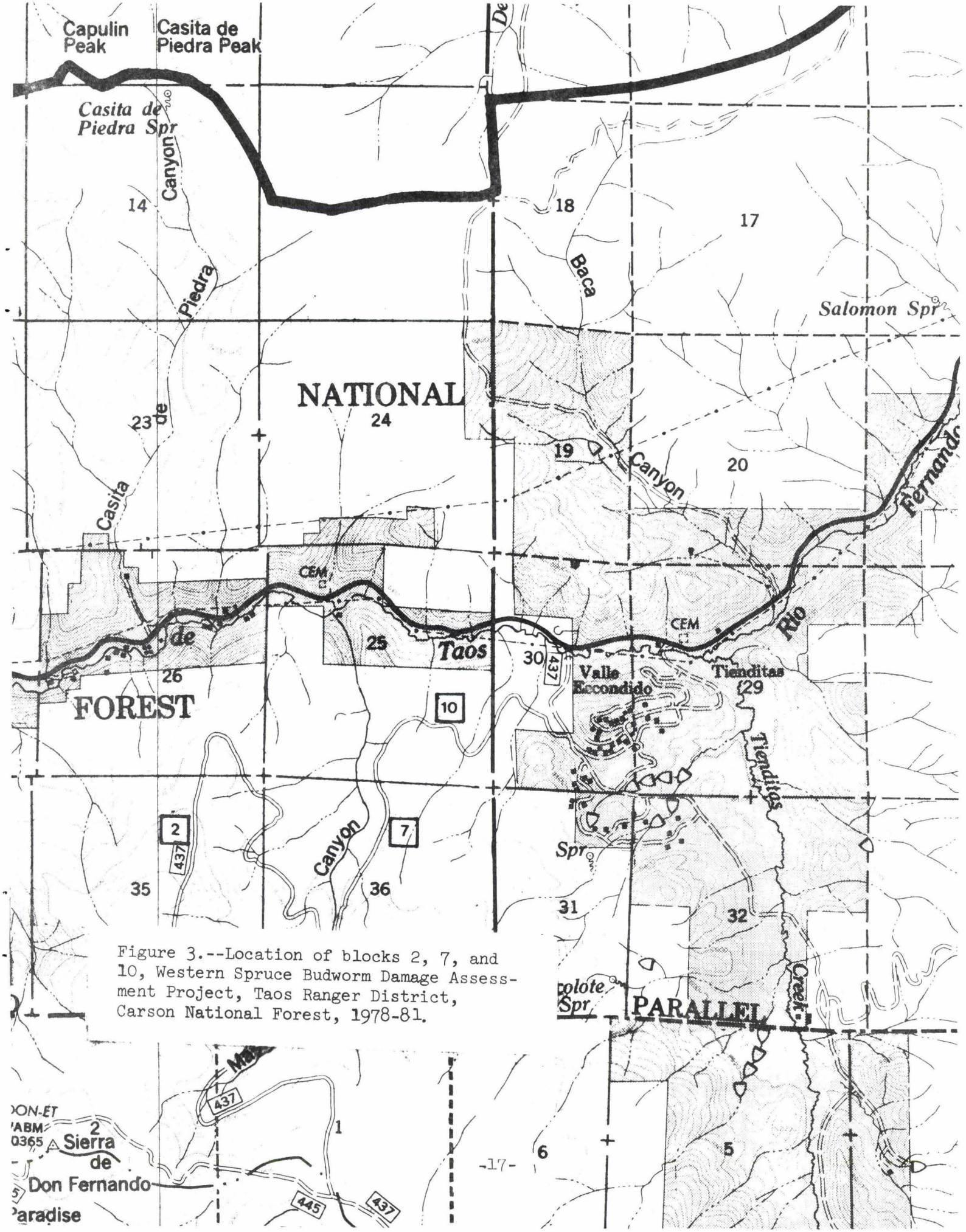

Figure 3.--Location of blocks 2, 7, and 10, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1978-81.

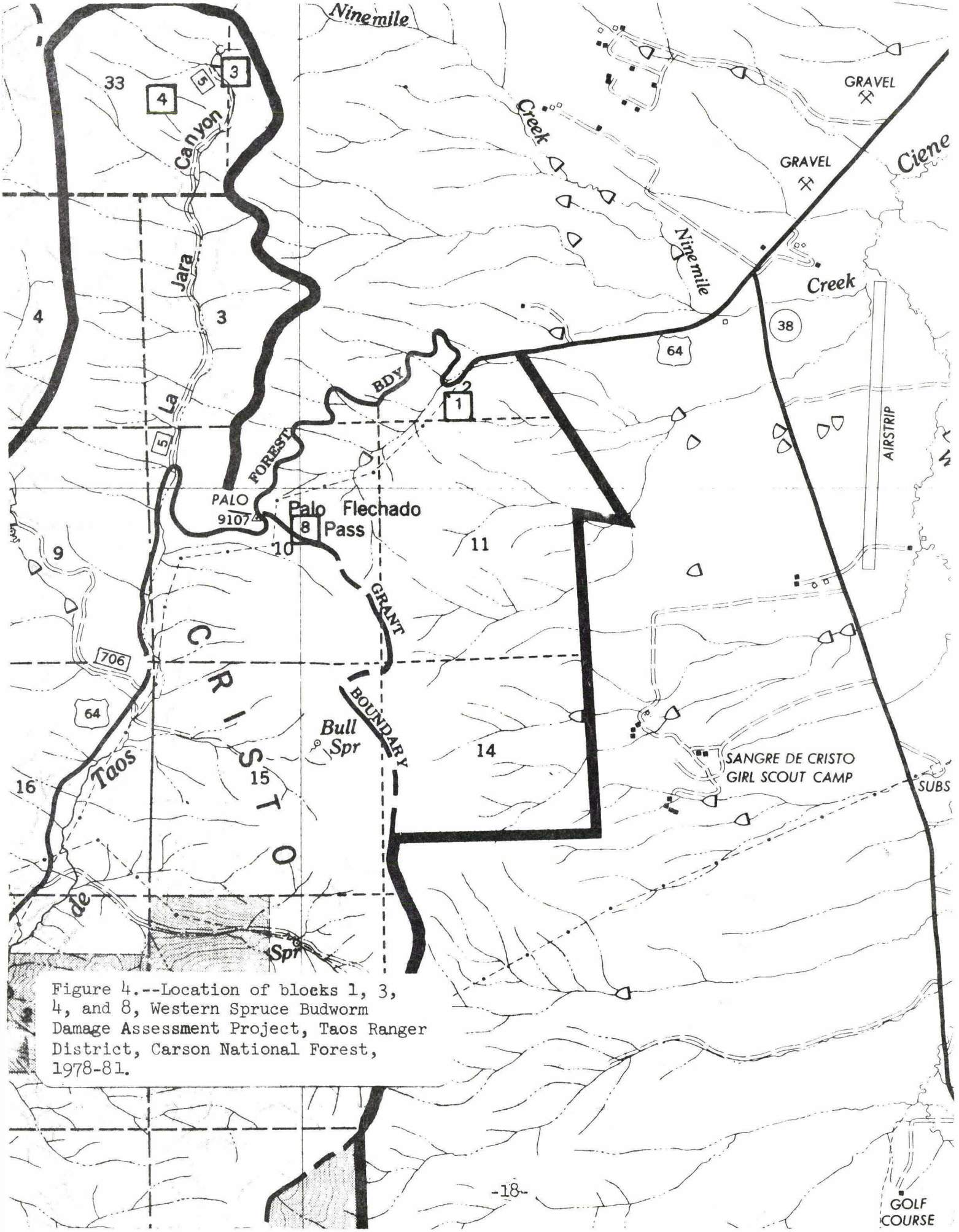

Figure 4.--Location of blocks 1, 3, 4, and 8, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1978-81.

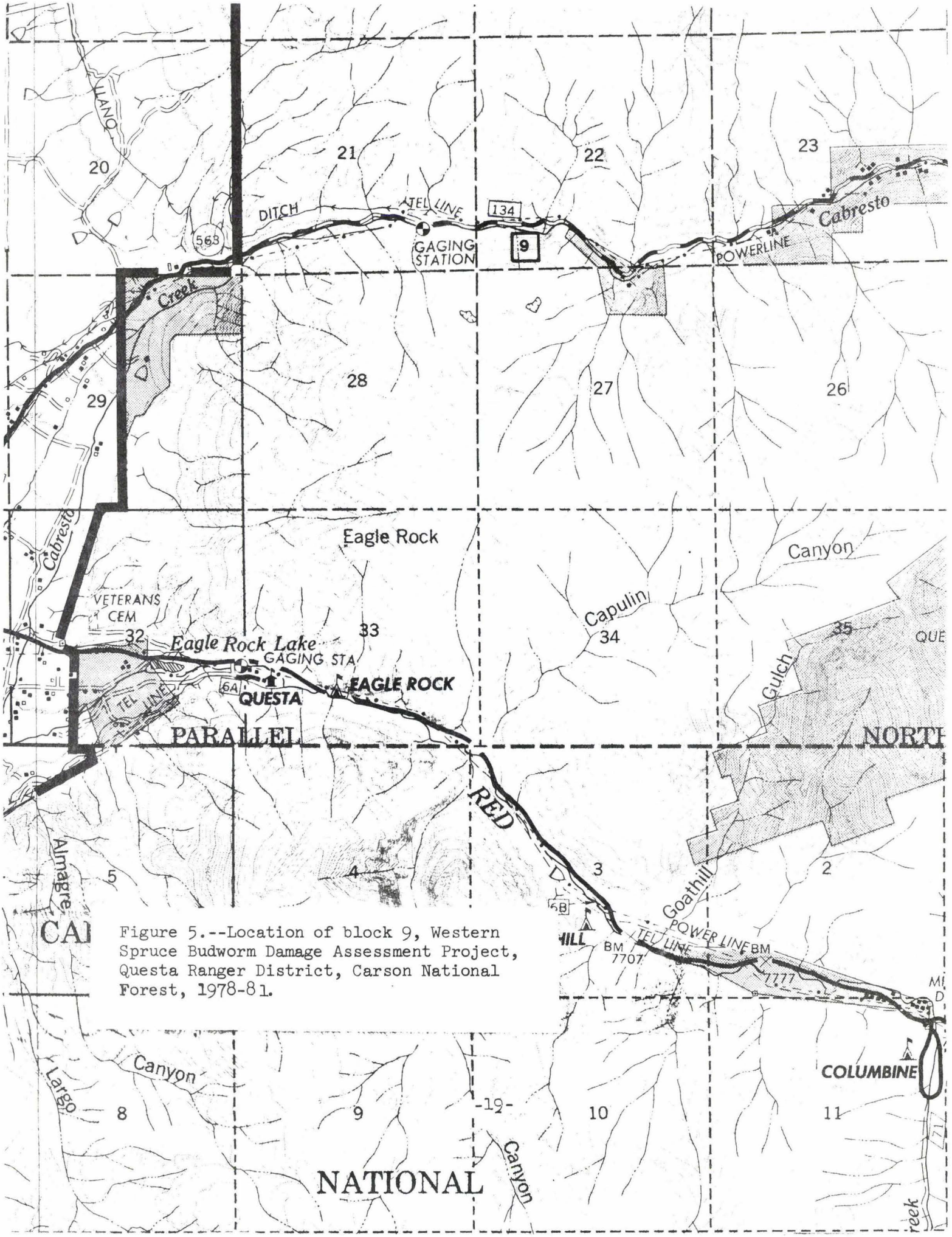

Figure 5.--Location of block 9, Western Spruce Budworm Damage Assessment Project, Questa Ranger District, Carson National Forest, 1978-81.

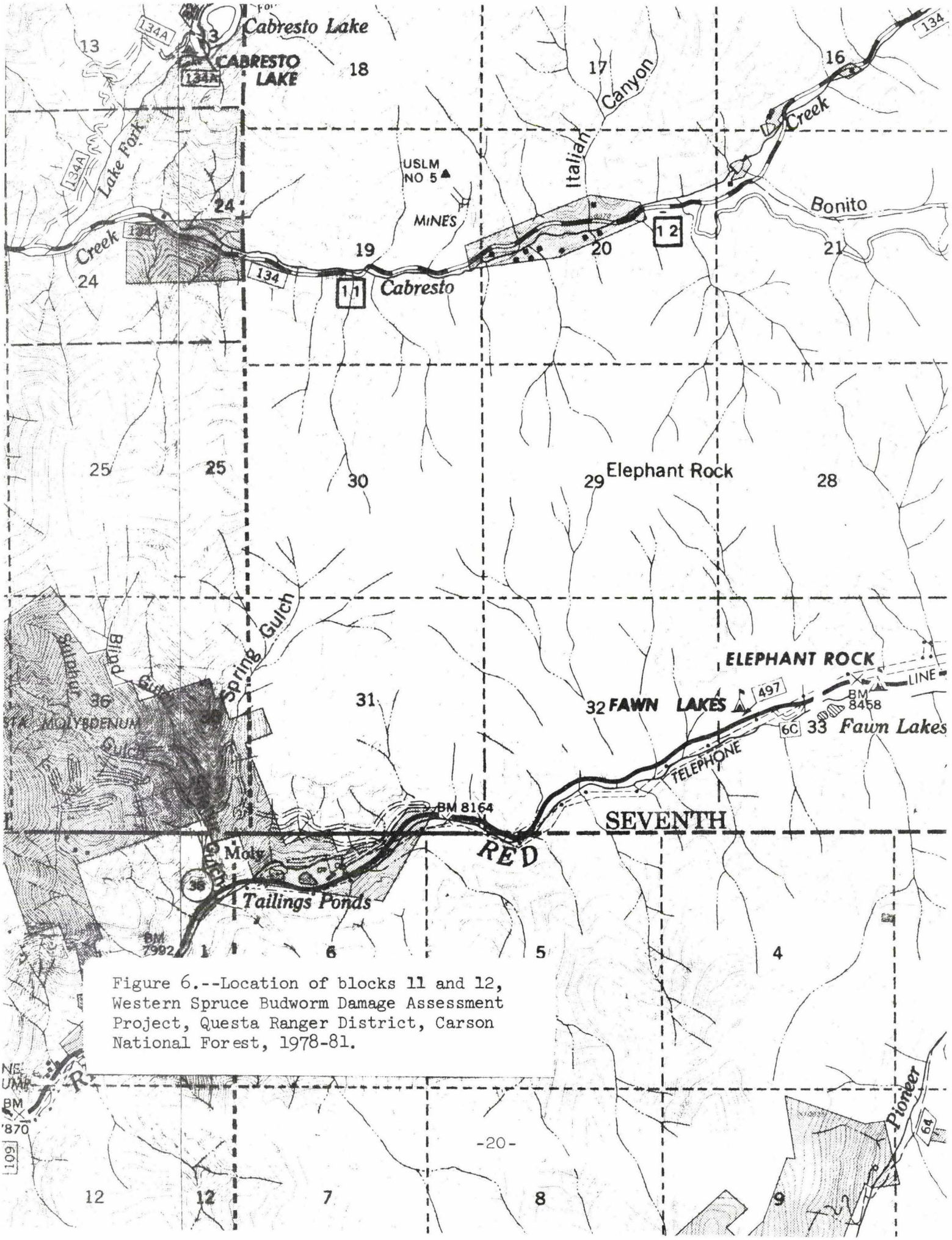

Figure 6.--Location of blocks 11 and 12, Western Spruce Budworm Damage Assessment Project, Questa Ranger District, Carson National Forest, 1978-81.

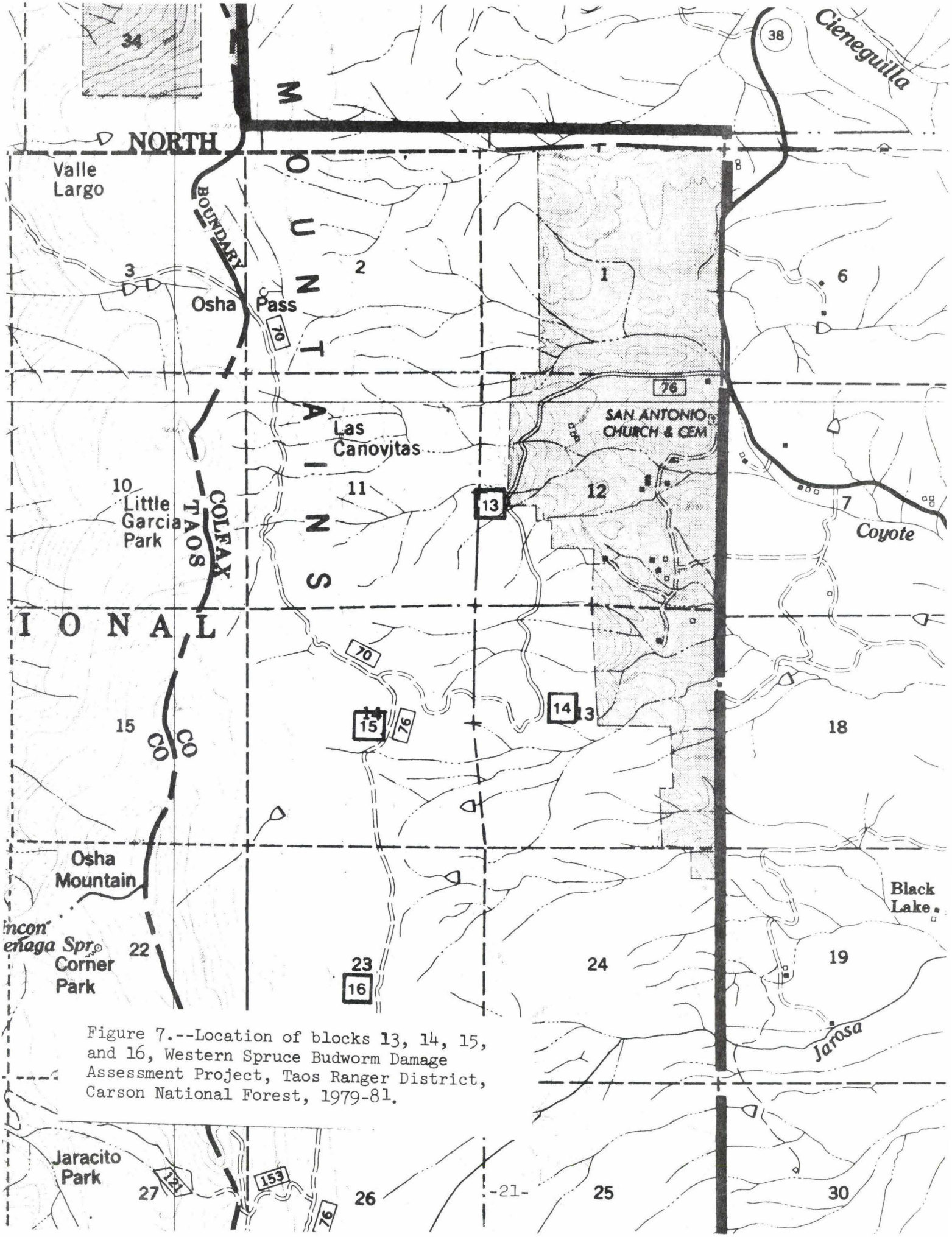

Figure 7.--Location of blocks 13, 14, 15, and 16, Western Spruce Budworm Damage Assessment Project, Taos Ranger District, Carson National Forest, 1979-81.

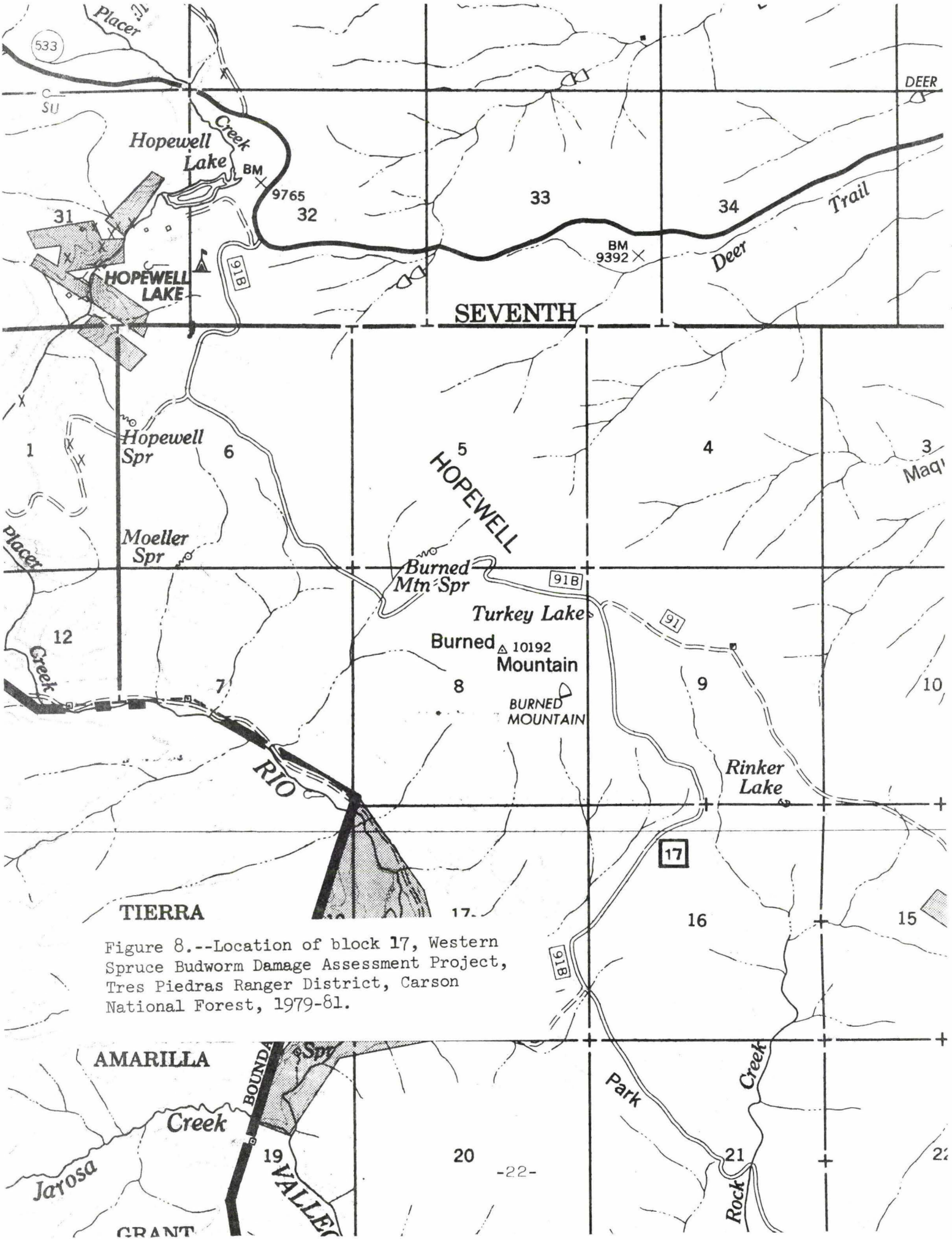

Figure 8.--Location of block 17, Western Spruce Budworm Damage Assessment Project, Tres Piedras Ranger District, Carson National Forest, 1979-81.

APPENDIX B

Stocking and species composition for blocks 1 through 12, 13 through 16, and 17

TABLE 1.--Tree species per acre vs. plot number, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FOR IT [illegible] 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) DOWNSTREAM FOR TJS
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
* PAGE 1 OF 2

V4	V2 COUNT / ROW PCT / COL PCT / TOT PCT	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	ROW TOTAL
DF		107	199	44	75	21	29	206	119	94	83	1180
DOUGLAS FIR		9.1	16.9	3.7	6.4	1.8	2.5	17.5	10.1	8.0	7.0	66.2
		54.9	87.7	44.9	65.8	29.6	44.6	82.4	72.6	70.1	50.0	
		6.0	11.2	2.5	4.2	1.2	1.6	11.6	6.7	5.3	4.7	
PP		3	12	0	0	42	14	38	26	36	61	233
PONDEROSA PINE		1.3	5.2	.0	.0	18.0	6.0	16.3	11.2	15.5	26.2	13.1
		1.5	5.3	.0	.0	59.2	21.5	15.2	15.9	26.9	36.7	
		.2	.7	.0	.0	2.4	.8	2.1	1.5	2.0	3.4	
SP		8	1	43	36	0	0	0	1	0	2	161
SPRUCE		5.0	.6	26.7	22.4	.0	.0	.0	.6	.0	1.2	9.0
		4.1	.4	43.9	31.6	.0	.0	.0	.6	.0	1.2	
		.4	.1	2.4	2.0	.0	.0	.0	.1	.0	.1	
WF		77	15	11	3	8	22	6	18	4	20	209
WHITE FIR		36.8	7.2	5.3	1.4	3.8	10.5	2.9	8.6	1.9	9.6	11.7
		39.5	6.6	11.2	2.6	11.3	33.8	2.4	11.0	3.0	12.0	
		4.3	.8	.6	.2	.4	1.2	.3	1.0	.2	1.1	
COLUMN TOTAL		195	227	98	114	71	65	250	164	134	166	1783
		10.9	12.7	5.5	6.4	4.0	3.6	14.0	9.2	7.5	9.3	100.0

(CONTINUED)

TABLE 1.--Tree species per acre vs. plot number, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico--Continued

SPSS FORMAT FOR JOB1,CARSON F 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) DOWNSTREAM FOR TJP
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
* PAGE 2 OF 2

V4	V2	11.	12.	ROW TOTAL
DF	COUNT	85	118	1180
DOUGLAS FIR	ROW PCT	7.2	10.0	66.2
	COL PCT	66.4	69.0	
	TOT PCT	4.8	6.6	
PP	COUNT	1	0	233
PONDEROSA PINE	ROW PCT	.4	.0	13.1
	COL PCT	.8	.0	
	TOT PCT	.1	.0	
SP	COUNT	22	48	161
SPRUCE	ROW PCT	13.7	29.8	9.0
	COL PCT	17.2	28.1	
	TOT PCT	1.2	2.7	
WF	COUNT	20	5	209
WHITE FIR	ROW PCT	9.6	2.4	11.7
	COL PCT	15.6	2.9	
	TOT PCT	1.1	.3	
COLUMN TOTAL		128	171	1783
		7.2	9.6	100.0

TABLE 2.--Tree category vs. plot number, Blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FOR [illegible] 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) UPSTREAM FOR TOP
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SPS10
SPS11 SPS12

* * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * *
V10 TREE CATAGORY BY V2 PLOT NUMBER
* PAGE 1 OF 2

V10	COUNT / ROW PCT / COL PCT / TOT PCT	V2 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	ROW TOTAL
POLE		145	138	43	55	13	28	157	80	70	110	1047
POLE TIMBER		13.8	13.2	4.1	5.3	1.2	2.7	15.0	7.6	6.7	10.5	58.7
		74.4	60.8	43.9	48.2	18.3	43.1	62.8	48.8	52.2	66.3	
		8.1	7.7	2.4	3.1	.7	1.6	8.8	4.5	3.9	6.2	
SAWT		50	89	55	59	58	37	93	84	64	56	736
SAW TIMBER		6.8	12.1	7.5	8.0	7.9	5.0	12.6	11.4	8.7	7.6	41.3
		25.6	39.2	56.1	51.8	81.7	56.9	37.2	51.2	47.8	33.7	
		2.8	5.0	3.1	3.3	3.3	2.1	5.2	4.7	3.6	3.1	
COLUMN TOTAL		195 10.9	227 12.7	98 5.5	114 6.4	71 4.0	65 3.6	250 14.0	164 9.2	134 7.5	166 9.3	1783 100.0

(CONTINUED)

TABLE 2.--Tree category vs. plot number, Blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FOR AT [illegible] 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) [illegible]
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
V10 TREE CATAGORY BY V2 PLOT NUMBER
* PAGE 2 OF 2

V10	V2	11.	12.	ROW TOTAL
	COUNT			
	ROW PCT			
	COL PCT			
	TOT PCT			
POLE		85	123	1047
POLE TIMBER		8.1	11.7	58.7
		66.4	71.9	
		4.8	6.9	
SALT		43	48	736
SAW TIMBER		5.8	6.5	41.3
		33.6	28.1	
		2.4	2.7	
COLUMN TOTAL		128	171	1783
		7.2	9.6	100.0

TABLE 3.--Summary of tree category vs. tree species, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WIDE CARD FILE 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) DOWNSTREAM FOR TJH
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* C R O S S T A B U L A T I O N O F *
V10 TREE CATAGORY BY V4 SPECIES
* PAGE 1 OF 1

	V4				
COUNT / ROW PCT / COL PCT / TOT PCT	DOUGLAS FIR (DF)	PONDEROSA PINE (PP)	SPRUCE (SP)	WHITE FIR (WF)	ROW TOTAL
V10					
POLE TIMBER	715	85	108	139	1047
	68.3	8.1	10.3	13.3	59.7
	60.4	36.5	67.1	66.5	
	40.1	4.8	6.1	7.8	
SAW TIMBER	465	148	53	70	736
	63.2	20.1	7.2	9.5	41.3
	39.4	63.5	32.9	33.5	
	26.1	8.3	3.0	3.9	
COLUMN TOTAL	1180	233	161	209	1783
	66.2	13.1	9.0	11.7	100.0

TABLE 4.--Tree species per acre vs. plot number, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR SP4.CARSON.DF 02/06/84

FILE SPSS (CREATION DAT = 02/04/84) DOWNSTREAM FOR TJR
SUBFILE SP13 SP14 SP15 SP16

* C R O S S T A B U L A T I O N O F *
V4 SPECIES BY V2 PLOT NUMBER
* PAGE 1 OF 1

V4	V2	13.	14.	15.	16.	ROW TOTAL
DF	COUNT	152	85	111	24	372
DOUGLAS FIR	ROW PCT	40.9	22.8	29.8	6.5	43.7
	COL PCT	93.3	43.6	62.7	7.6	
	TOT PCT	17.9	10.0	13.0	2.8	
PP	COUNT	0	48	0	0	48
PONDEROSA PINE	ROW PCT	.0	100.0	.0	.0	5.6
	COL PCT	.0	24.6	.0	.0	
	TOT PCT	.0	5.6	.0	.0	
SP	COUNT	3	4	55	238	300
SPRUCE	ROW PCT	1.0	1.3	18.3	79.3	35.3
	COL PCT	1.8	2.1	31.1	75.3	
	TOT PCT	.4	.5	6.5	28.0	
TF	COUNT	0	0	0	54	54
TRUE FIR	ROW PCT	.0	.0	.0	100.0	6.3
	COL PCT	.0	.0	.0	17.1	
	TOT PCT	.0	.0	.0	6.3	
WF	COUNT	8	58	11	0	77
WHITE FIR	ROW PCT	10.4	75.3	14.3	.0	9.0
	COL PCT	4.9	29.7	6.2	.0	
	TOT PCT	.9	6.8	1.3	.0	
COLUMN TOTAL		163 19.2	195 22.9	177 20.8	316 37.1	851 100.0

TABLE 5.--Tree category vs. plot number, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR 'DUNK.CARSON' F 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) 'UPSTREAM FOR TJR'
SUBFILE SP13 SP14 SP15 SP16

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V10 TREE CATAGORY BY V2 PLOT NUMBER
* PAGE 1 OF 1

	V2				
	COUNT / ROW PCT / COL PCT / TOT PCT	13.	14.	15.	16.	ROW TOTAL
V10						
POLE		117	118	86	252	573
POLE TIMBER		20.4	20.6	15.0	44.0	67.3
		71.8	60.5	48.6	79.7	
		13.7	13.9	10.1	29.6	
SAWT		46	77	91	64	278
SAW TIMBER		16.5	27.7	32.7	23.0	32.7
		28.2	39.5	51.4	20.3	
		5.4	9.0	10.7	7.5	
COLUMN TOTAL		163	195	177	316	851
		19.2	22.9	20.8	37.1	100.0

TABLE 6.--Summary of tree category vs. tree species, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW.CARSON NF 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) DOWNSTREAM FOR TJF
SUBFILE SF13 SF14 SF15 SF16

* C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * * *
V10 TREE CATAGORY BY V4 SPECIES
* PAGE 1 OF 1

V10	V4 COUNT / ROW PCT / COL PCT / TOT PCT	DOUGLAS FIR (DF)	PONDEROSA PINE (PP)	SPRUCE (SP)	TRUE FIR (TF)	WHITE FIR (WF)	ROW TOTAL
POLE		195	31	266	33	48	573
POLE TIMBER		34.0	5.4	46.4	5.8	8.4	67.3
		52.4	64.6	88.7	61.1	62.3	
		22.9	3.6	31.3	3.9	5.6	
SAWT		177	17	34	21	29	278
SAW TIMBER		63.7	6.1	12.2	7.6	10.4	32.7
		47.6	35.4	11.3	38.9	37.7	
		20.9	2.0	4.0	2.5	3.4	
COLUMN TOTAL		372	48	300	54	77	851
		43.7	5.6	35.3	6.3	9.0	100.0

TABLE 7.--Tree species per acre vs. plot number, block 17. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR ASR4,CARSON NF 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) RUNSTREAM FOR TJR
SUBFILE SP17

* * * * * * * * * * * * * * * * * * * CROSSTABULATION OF * * * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
* PAGE 1 OF 1

V4	V2 17.	ROW TOTAL
DF	165	165
DOUGLAS FIR	100.0	81.7
	81.7	
	81.7	
SP	22	22
SPRUCE	100.0	10.9
	10.9	
	10.9	
WF	15	15
WHITE FIR	100.0	7.4
	7.4	
	7.4	
COLUMN TOTAL	202 100.0	202 100.0

TABLE 8.--Tree category vs. plot number, block 17. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW.CARSON NF 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) DOWNSTREAM FOR TJS
SUBFILE SP17

* C R O S S T A B U L A T I O N O F *
V10 TREE CATAGORY BY V2 PLOT NUMBER
* * * * * * * * * * * * * * * * * * * \

TABLE 9.--Summary of tree category vs. tree species, block 17. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW.CARSON.F 02/06/84

FILE SPSS (CREATION DATE = 02/06/84) DOWNSTREAM FOR TJF
SUBFILE SP17

* * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
V10 TREE CATAGORY BY V4 SPECIES
* PAGE 1 OF 1

V10	V4 COUNT / ROW PCT / COL PCT / TOT PCT	DOUGLAS FIR DF	SPRUCE SP	WHITE FIR WF	ROW TOTAL
POLE		82	18	5	105
POLE TIMBER		78.1	17.1	4.8	52.0
		49.7	81.8	33.3	
		40.6	8.9	2.5	
SAWT		83	4	10	97
SAW TIMBER		85.6	4.1	10.3	48.0
		50.3	18.2	66.7	
		41.1	2.0	5.0	
COLUMN TOTAL		165 81.7	22 10.9	15 7.4	202 100.0

APPENDIX C

Defoliation data: 1978-83

TABLE 10.--Percent defoliation to Douglas-fir on 1-acre sample blocks, WSBW damage assessment project, Carson National Forest, New Mexico, 1978-83[1 2]

	Percent defolation: 6-class system					
Block No.	1978	1979	1980	1981	1982	1983
1	47.5	81.1	85.7	84.2	25.4	16.1
2	47.0	80.2	80.8	96.4	33.3	31.4
3	64.8	86.0	79.5	91.9	20.3	17.4
4	69.1	86.9	77.6	79.9	28.8	16.1
5	65.6	93.4	79.9	89.0	76.4	47.3
6	22.0	60.2	80.9	98.9	24.1	33.1
7	54.6	89.6	79.0	84.9	42.7	31.3
8	66.5	93.1	84.0	95.1	32.9	15.0
9	11.7	29.1	66.0	82.6	74.7	18.8
10	70.2	90.6	82.6	92.8	37.8	46.9
11	60.7	95.2	99.5	62.9	91.9	57.8
12	50.7	94.7	99.6	68.8	91.8	64.9
1-12 $\bar{x}$	52.5	81.7	82.9	85.6	48.3	27.6
13[3]		12.7	45.9	99.9	40.3	37.2
14		9.7	36.1	97.9	60.0	44.4
15		7.5	20.4	93.9	71.2	18.3
16		1.4	1.8	75.5	80.4	13.6
13-16 $\bar{x}$		7.8	26.1	91.8	63.0	28.4
17[4]			25.7	27.5	56.6	17.3

[1] Each block percentage is the average of 10 single-tree samples from 1978-82 and 5 single-tree samples in 1983.
[2] Blocks 1 through 12 were established in 1978; 13 through 17 in 1979.
[3] Budworm first observed in 1979.
[4] Budworm first observed in 1980.

APPENDIX D

Radial growth assessment of WSBW-infested Douglas-fir trees on the Carson National Forest, New Mexico

RADIAL GROWTH ASSESSMENT

OF

WESTERN SPRUCE BUDWORM INFESTED DOUGLAS-FIR TREES

ON THE

CARSON NATIONAL FOREST, NEW MEXICO

A Report Prepared by:

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For:

Forest Pest Management
State and Private Forestry
Southwestern Region, Forest Service, USDA
517 Gold Avenue, S.W.
Albuquerque, New Mexico 87102

November 3, 1983

ABSTRACT

Growth of western spruce budworm (WSBW) infested Douglas-fir (Pseudotsugae menziesii) forests on the Carson National Forest, New Mexico, was assessed through dendrochronological analysis of increment cores extracted at breast height. Comparisons of indexed and filtered host and non-host (ponderosa pine [Pinus ponderosa]), tree-ring chronologies revealed that host tree growth was reduced during past and present WSBW outbreaks. The non-host chronologies were used to remove the non-WSBW growth effects from the host chronologies, and the corrected host tree growth indices were then used to assess growth loss during known outbreak periods. Maximum growth loss during one year was generally greater than 50 percent. The average growth loss for five year periods during outbreaks was approximately 30 to 40 percent, and the maximum growth loss between two years during an outbreak was usually more than 50 percent.

INTRODUCTION

Western spruce budworms, Choristoneura occidentalis Freeman, have repeatedly defoliated conifer trees throughout forested areas of North America. Mixed conifer and spruce-fir forests of the southwestern United States have not been immune to the recurrent damaging effects of this insect. The most recent infestation on the Carson National Forest, New Mexico, has resulted in defoliation of more than 100,000 acres (40,471 ha) of Douglas-fir (Pseudotsugae menziesii), true firs (Abies spp.), and spruce Picea spp.) (Stein 1981).

In 1978 a damage assessment project was undertaken to measure the extent of defoliation and amounts of topkill, mortality, and growth loss. This report describes preliminary results of a study designed to assess the effects of western spruce budworm (WSBW) on radial growth of surviving trees. The two primary objectives of this study were to (1) determine if current and previous periods of WSBW defoliations could be detected in Douglas-fir tree-ring series, and (2) to measure any observable growth loss.

Tree-rings have been used to measure the effects of WSBW activity by Blais (1965) and Mott and others (1957) in balsam fir forests (Abies balsamea) in the eastern United States, and by Brubaker and Greene (1978) and Carlson and McCaughey (1982) in Douglas-fir forests in the west. This study is the first effort to assess WSBW activity in southwestern mixed conifer forests using dendrochronology.

The objectives of this study have been effectively met, however, additional collections and analyses would help to verify the findings. Furthermore, the success of the methods employed in this study indicate that other growth assessment investigations may also provide useful information. A description of future work that would help to improve and expand growth loss estimates is included at the end of this report.

Records of WSBW on the Carson National Forest

Records of WSBW occurrence in the Southwestern Region (R-3) were summarized by Lessard (1975). Additional information on the extent and timing of infestations was obtained from Annual Insect Reports prepared by Regional Office personnel from 1924 to 1956, and from reports and documents filed by forest entomologists and other officials following area inspections (files temporarily located at Laboratory of Tree-Ring Research).

The records indicate that there have been at least four major outbreaks of WSBW on the Carson National Forest since the 1920's. WSBW activity was first recorded in Region 3 in 1922 on the western division of the Carson. This infestation apparently remained on the western side of the Rio Grande. WSBW was first recorded on the eastern division of the Carson in 1940, and was reported as epidemic in 1944 but not so heavy in 1945. WSBW populations declined after 1946, but remained present in many areas, causing only slight damage during the late 1940's.

Populations increased again throughout the mixed conifer types in northern New Mexico in the late 1950's. This outbreak reached a high of approximately 1 million acres infested in 1961, declining somewhat in 1963. This infestation persisted through the mid-1960's with isolated and smaller infested areas appearing in the late 1960's and early 1970's.

The most recent widespread outbreak of WSBW was first noticed on the Taos Indian Reservation in 1975, with infested areas gradually increasing in size since that time. Large areas have sustained light to severe defoliation on both the eastern and western divisions of the Carson, as well as areas on the Santa Fe and Cibola National Forests (Stein 1981).

METHODS

Collections

In July 1982 increment core collections were obtained from five different study areas on the Taos, Questa, and Tres Piedras Ranger Districts. Increment cores were taken from host trees and non-host trees so that growth comparisons could be made. The sample host trees were all Douglas-fir and the non-host trees were all ponderosa pine (Pinus ponderosa), with the exception of one piñon (Pinus edulis) collection from Cabresto Canyon on the Questa Ranger District. Each of the host and non-host collections consisted of two increment cores from each of 15 to 30 trees. Table 1 lists the number of trees used in the analyses, and other characteristics of the collection sites. The collection sites were located within and around one-acre study blocks that were established in 1978 and 1979 for long term monitoring of WSBW activity (Stein 1981).

Laboratory Preparations

Increment cores were mounted in wooden holders and sanded. The annual rings of all samples were crossdated by the skeleton plot technique (Stokes and Smiley 1968) to assure that accurate calendar year dates of formation were assigned to individual rings. This is an essential step in tree-ring analysis because locally absent rings and false rings are not uncommon in conifer trees, especially if the trees have survived stressful conditions such as drought or insect defoliations. The original dating of each core was checked by a second dendrochronologist.

The crossdated annual rings of each specimen were measured on a sliding stage micrometer interfaced with an Apple II+ microcomputer (Robinson and Evans 1980). Measurements were to within 0.01 millimeter. Original measurements were checked for accuracy by remeasuring approximately one fifth of the rings on each core. A statistical test was then

Table 1. Number of trees sampled and characteristics of collection sites. Species abreviations are Pseudotsugae menziesii (PSME), Pinus ponderosa (PIPO), Pinus edulis (PIED), Abies concolor (ABCO).

	Capulin Canyon (CPN)	Garcia Park (GAR)	Cabresto Canyon (CAB)	Osha Mountain (OSH)	Burned Mountain (BRN)
No. of Trees[1]					
PSME	17	17	10	11	19
PIPO	12	18		20	
PIED			18		
Block No.s[2]					
	6	7	9	16	17
Species Composition[3] (%)					
PSME	44	83	70	12	82
ABCO	30	2	3	17	7
PIPO	26	15	27	71	11
Elevation					
	9,600 ft. (2,926 m)	8,800 ft. (2,682 m)	8,600 ft. (2,438 m)	9,600 ft. (2,926 m)	9,700 ft. (2,956 m)

[1]Number of trees at CPN, GAR, and CAB are the number used in the analyses described in this report. Number of trees at OSH and BRN are number sampled but have not been analyzed yet.

[2]Trees were sampled within and around one-acre study blocks established in 1978 and 1979. Descriptions and maps of study blocks are included in Stein (1981).

[3]Data from Stein (1981).

applied to determine whether the original measurements were acceptable or required remeasurement (Burns 1979).

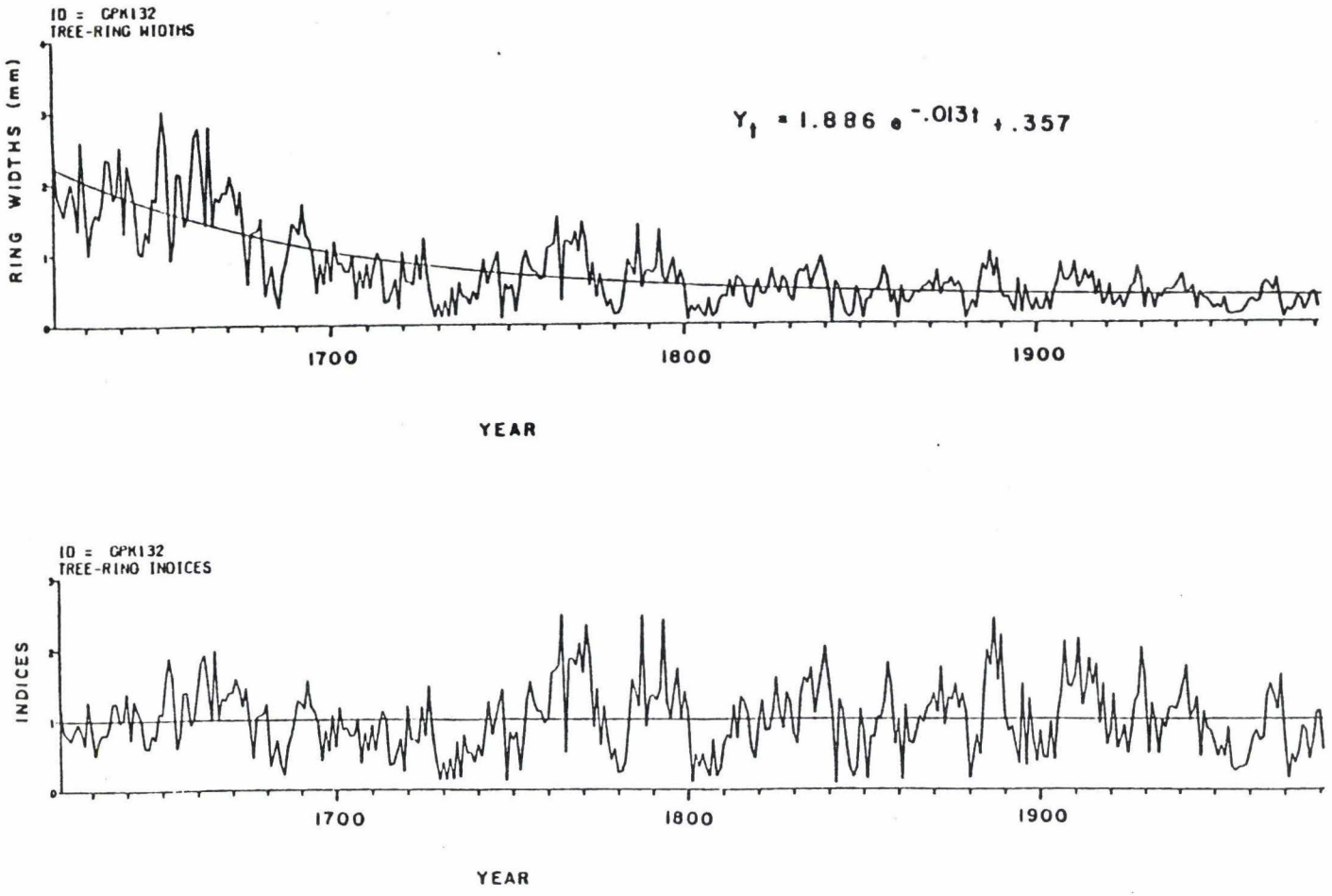
Standardization and Computer Analyses

Three paired sets of host and non-host ring-width measurements have been processed through numerical transformations and analyses that are described in this section. These tree-ring samples were collected from the eastern division of the Carson National Forest at Capulin Canyon (CPN) and Garcia Park (GAR) on the Taos Ranger District, and from Cabresto Canyon (CAB) on the Questa Ranger District.

All ring-width measurements were plotted (fig. 1) so that growth trends could be observed. Most of the specimens displayed the typical "biological growth trend", which is characterized by large ring widths and high variability near the pith, and smaller rings and lower variability near the bark. This trend is primarily due to the aging of the tree and increasing circumference of the tree bole (Fritts 1976).

In order to facilitate the averaging together of many tree-ring series of different lengths, and to make the variance of the inner portion of each series equivalent to the outer portions, it was necessary to standardize the ring-width measurements into growth index values (Fritts 1976, Graybill et al. 1982). This was accomplished with a program called INDEX (Graybill 1979), which effectively removes growth trends from ring-width series. The computer procedures involved the fitting of a negative exponential curve, straight line of negative slope, or horizontal line, to each ring-width series, depending on the general shape of the biological growth trend (fig. 1). Each ring-width value was then divided by the corresponding value of the fitted line at that point.

Figure 1. Plots of ring widths and growth indices of a ponderosa pine sampled at Garcia Park. The negative exponential growth curve that was fit to the ring-width series by the program INDEX is shown at the top. Division of each ring-width value by the corresponding value of the fitted line produces the index values shown at the bottom. The horizontal line is the approximate mean of the series.



The fitted curve or line can be considered the expected growth of the tree if no environmental influences, such as climatic change or insect defoliations, were affecting the tree. The result of standardization is a set of growth indices (fig. 1) that vary about a mean of approximately 1.0 (the expected growth for any given year).

Indexed tree-ring series are very useful because they can be averaged together to form summary chronologies for a tree and for a site. Ring-width series of different lengths cannot be meaningfully averaged because the large ring widths on the inner portion of shorter series would create a rise in the averaged series and would also create a higher variance at that point. Index series are also convenient because they provide a standard reference to expected tree growth, which is the mean of the series.

The summing or averaging of the tree-ring series at each site was accomplished with the program SUMAC (Graybill 1979). This program averages the two series from each tree into a tree summary, and then as a final step, averages all the tree summaries into a final summary for the site. SUMAC also computes an analysis of variance and correlation for a period of years common to all series used in the summation.

All of the individual tree summaries, final summaries for the host trees, and final summaries of the non-host trees were processed through two other transformations. The first was a filtering procedure that emphasized long term changes in the indexed tree-ring series for graphical comparison of host and non-host tree growth. Since WSBW outbreaks typically build gradually and may last 10 or more years (Lessard 1975, Carlson, et al. 1983), the effects on tree growth are probably observable over relatively long periods of time. The filtering procedure effectively removes the variation occurring at shorter intervals, which tends to obscure the comparisons of host and non-host series.

Figure 2 is a plot of the Capulin Canyon Douglas-fir final summary with the low pass filtered series overlaid on the index series. The low pass filter smoothes the index series by multiplying each index value and surrounding values by a set of symmetrically weighted values (Mitchell, et al. 1965).

The second transformation was a correction of the host tree series by subtracting non-host series, which were first scaled to the same variance as the host tree series. The corrected host tree series retain the variations in tree growth that were not in common between the host and non-host series. Thus, WSBW effects on the host trees were presumably retained in the corrected index series, while the effects of other environmental influences to which both host and non-host were responding (eg., climate), were removed. This technique was first developed by Nash, Fritts and Stokes (1975) for a study of the effects of copper smelter pollutants on tree growth in central Arizona. The computer program TRMCLM utilizes the following equations to derive corrected indices:

$$PRI = \frac{SDEV(H)}{SDEV(NH)} \left((INDEX(NH) - MEAN(NH) \right)$$

$$CI = INDEX(H) - PRI$$

PRI is the predicted residual index value for each year of the non-host series, SDEV(H) and SDEV(NH) are the standard deviations for the host and non-host series, INDEX(NH) and INDEX(H) are each index value of the host and non-host series respectively, MEAN(NH) is the mean of the non-host series (about 1.0), and CI is the corrected index value for each year of the host tree.

In this study, the use of the TRMCLM technique was based on two assumptions. First, the host and non-host trees were assumed to be

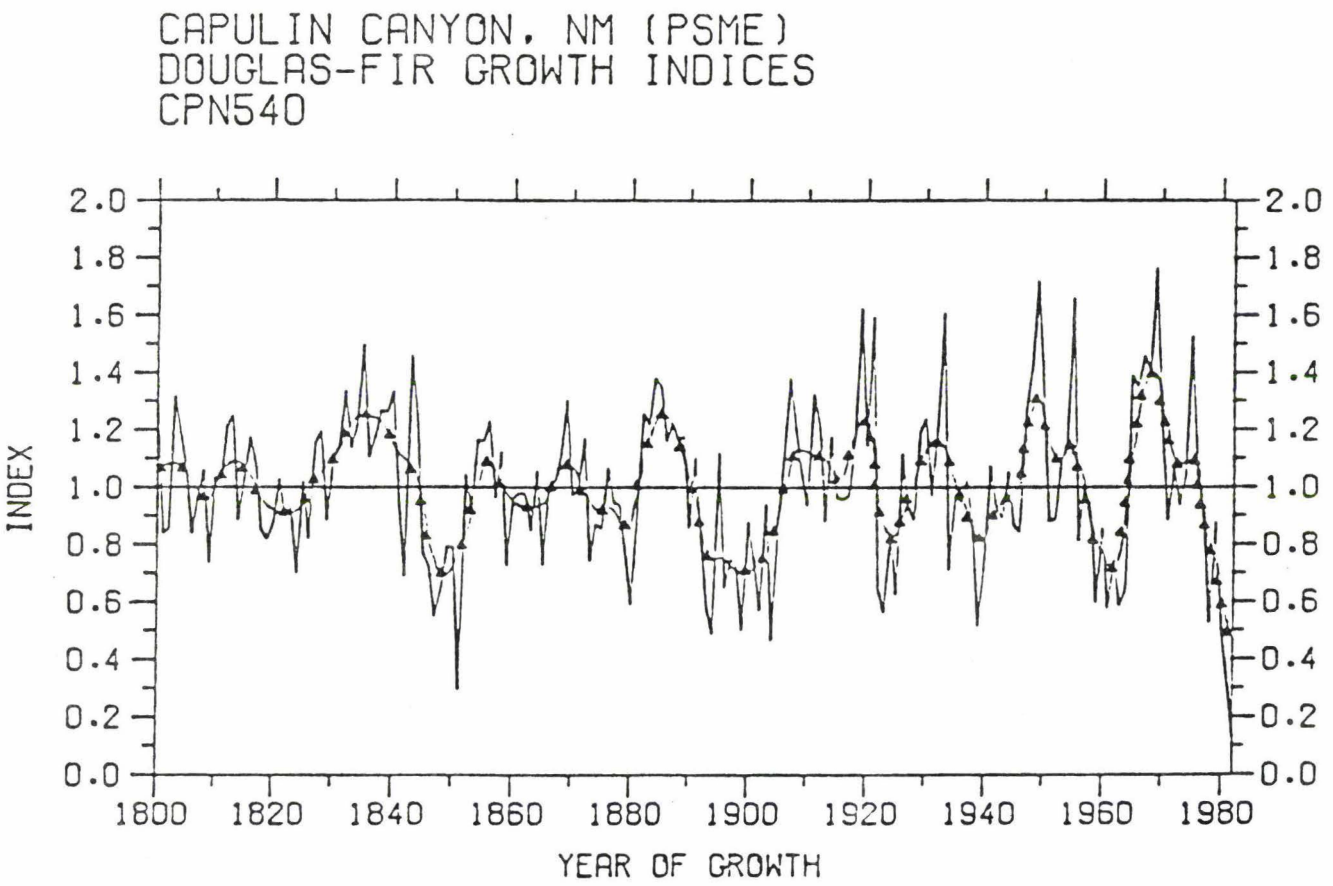


Figure 2. Plot of Douglas-fir final summary indices (line) and low pass filter values (triangles). The low pass filter preserves most of the variance with wavelengths greater than approximately 8 years.

responding in a similar manner to environmental influences other than WSBW. This was probably a reasonable assumption since most of the variation in tree growth, especially in the Southwest, is due to variation in climate (Fritts 1976), and Douglas-fir and ponderosa pine at this particular location probably have a fairly similar response to climate (H. C. Fritts, pers. comm.). Response of pinon and Douglas-fir at the CAB site to climate may have been significantly different. This problem will be discussed in the results section.

Second, since WSBW does not ordinarily feed on ponderosa pine or piñon foliage, the non-host trees were assumed to be unaffected by WSBW. However, other researchers have found that non-host trees growing within the same stand as host trees may actually grow more rapidly than expected because of the reduced competition from nearby defoliated host trees (Carlson and McCaughey 1982). Thus, if the non-host trees were affected in this manner then the corrected indices would overestimate growth losses due to WSBW.

The Douglas-fir and ponderosa pine were mixed in the same stand at the CPN site, and the ponderosa pine sampled at GAR were in a stand that was close to, but separate from, the Douglas-fir. The piñon trees sampled at CAB were completely separate from the sampled Douglas-fir. Therefore, the effects of WSBW at CPN may be overestimated by the corrected indices, but this is probably not a problem with the GAR and CAB corrected indices.

It is also possible that the corrected indices underestimate growth loss in the host trees. Researchers have found that defoliated trees sustain the most severe growth loss within the crown portion of the tree stem (Mott et al. 1957). Since all of the measurements used in this study were from the base of the sample trees, the growth loss estimates, at least at the GAR site, are probably conservative.

Measures of Growth Loss

The final step in the analysis was the quantification of growth loss that was identified by the filtered series comparisons, and the corrected host tree indices. Three different measures that were first used by Brubaker and Greene (1979) were utilized in this study, and are presented in histogram form in the results section:

1. Maximum Growth Loss for One Year. This was the largest growth loss for a single year during each of the known periods of infestation. It was computed by subtracting the minimum index value during an infestation from the expected growth value (1.0), and then multiplying by 100 to give growth loss as a percent of expected growth.

2. Five Year Growth Loss. This was the average growth loss for a five year period, centered on the minimum index year during an infestation. It was computed by summing the index values for the five year period, subtracting the sum from 5.0 (the sum of expected growth indices during that period), dividing by 5.0, and then multiplying by 100 to give growth loss as a percent of expected growth.

3. Maximum Rate of Growth Reduction. This was the largest growth loss between two years during an infestation period. It was computed by finding the largest difference between the index values for two consecutive years and then multiplying the difference by 100 to give growth loss as a percent of expected growth.

RESULTS AND DISCUSSION

Comparisons of Filtered Growth Values

Graphical comparisons of the host and non-host tree-ring series revealed that growth loss was observable during three of the past WSBW infestations on the Carson. Comparisons of the three sites that have been

processed through standardization and filtering are shown in figure 3. The minimum filtered index values during periods of known WSBW infestation are indicated with arrows. It can be seen that Douglas-fir growth is noticeably less than ponderosa pine growth in the CPN and GAR comparisons, while the CAB comparison is not conclusive.

Although the differences between Douglas-fir and ponderosa pine growth in the CPN and GAR series are not particularly striking, it should be noted that these are comparisons of the final summaries, in which all tree summaries from each site are included. Comparisons of individual Douglas-fir tree summaries with the corresponding non-host final summary from the same site indicate that the effects of WSBW vary from one tree to another. Some trees apparently suffered no growth loss during some infestations, while others were markedly affected by several infestations. Thus, when all tree summaries are averaged into the final summary, the growth effects of the infestation are muted.

Figures 4 and 5 show comparisons of selected individual Douglas-fir tree summaries with the corresponding ponderosa pine final summaries. The major infestation in the mid-1940's appears in almost all of the Douglas-fir trees sampled at CPN and GAR, while the early-1960's and present infestations are represented by fewer trees.

Although the differences in growth between the non-host and host series are generally greatest during the known periods of infestation, there are other portions of the series where there are either positive or negative differences. For instance, during the 1890's Douglas-fir growth at GAR was below ponderosa pine growth in most of the sampled trees. This difference may also have been caused by WSBW, however, since there is no independent documentation of an infestation during this period, the actual

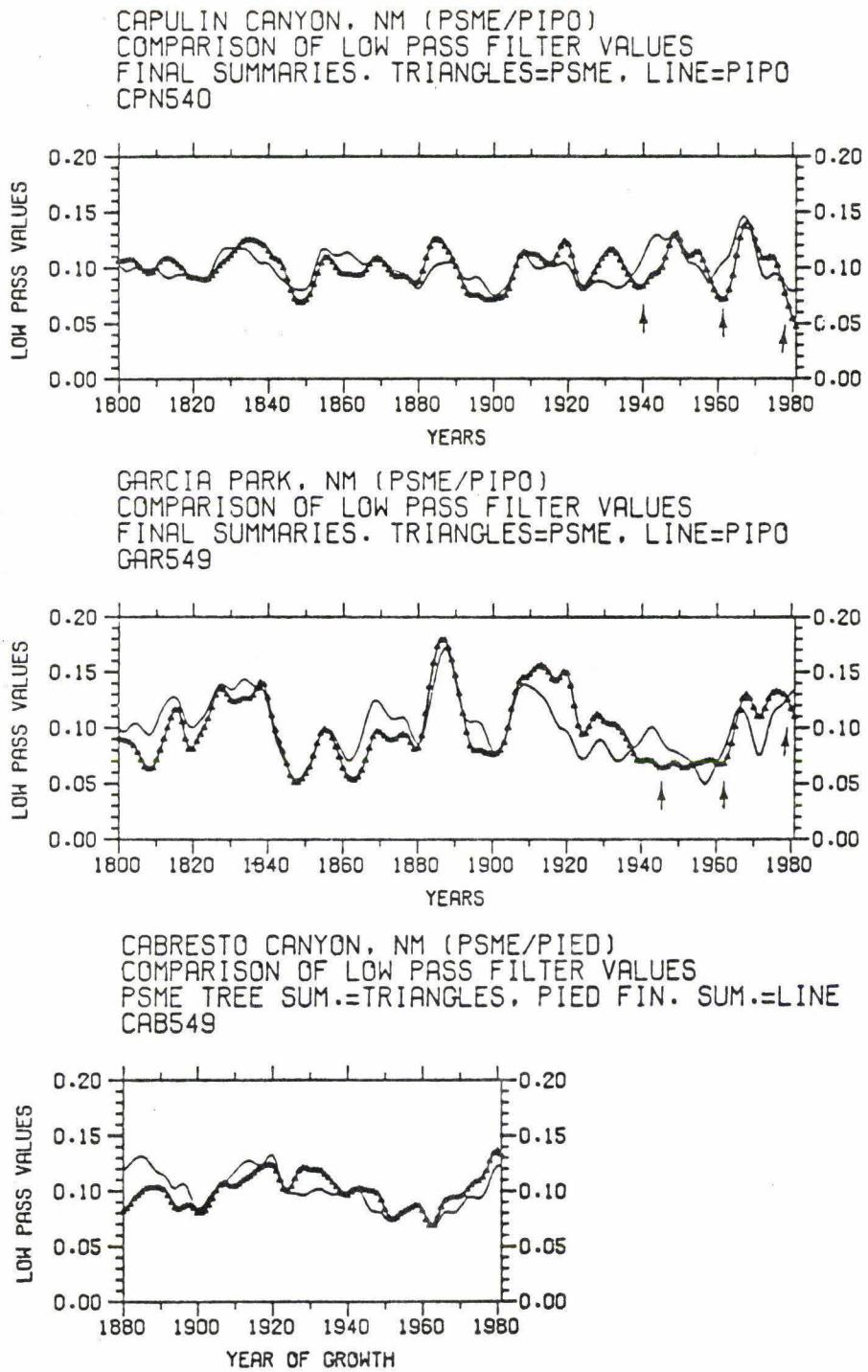


Figure 3. Plots of low pass filtered values of Douglas-fir and ponderosa pine final summaries. The lowest Douglas-fir growth values during known infestation periods are shown with arrows.

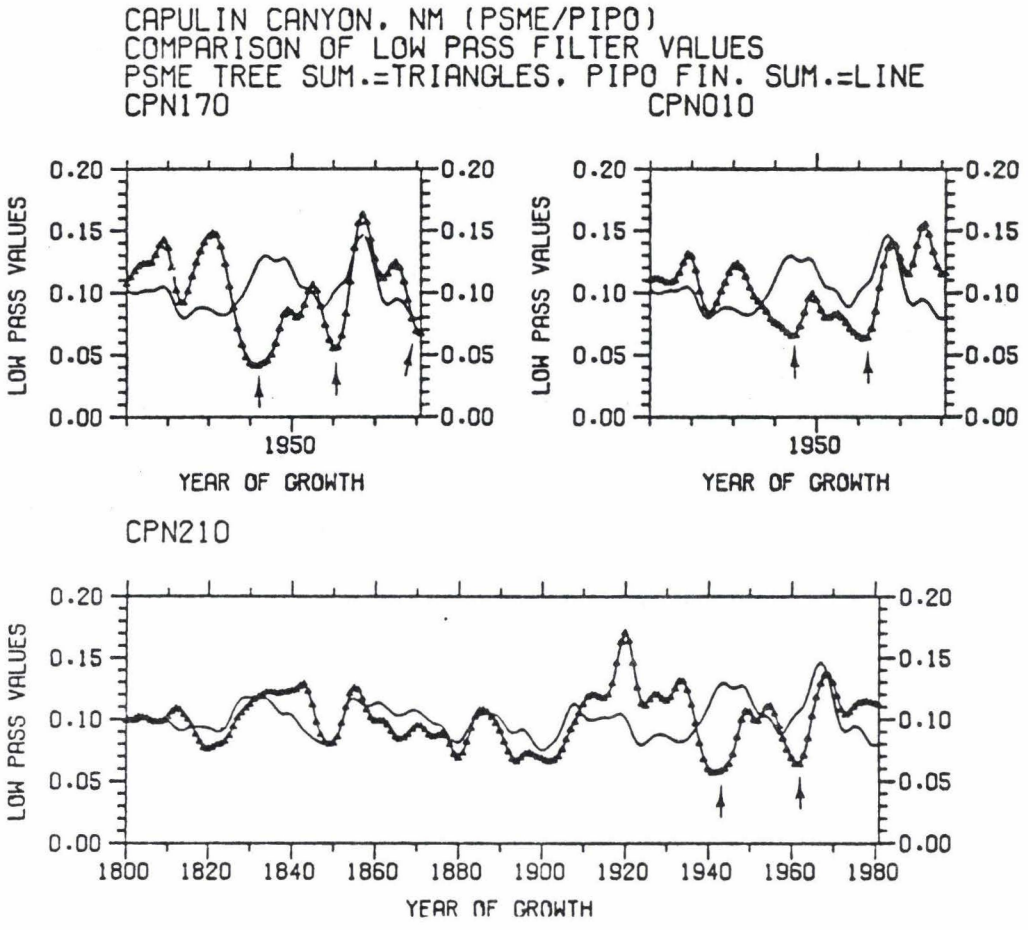


Figure 4. Plots of low pass filtered values of selected Douglas-fir trees and the ponderosa pine final summary from Capulin Canyon. Periods of lowest Douglas-fir growth during known infestations are shown with arrows.

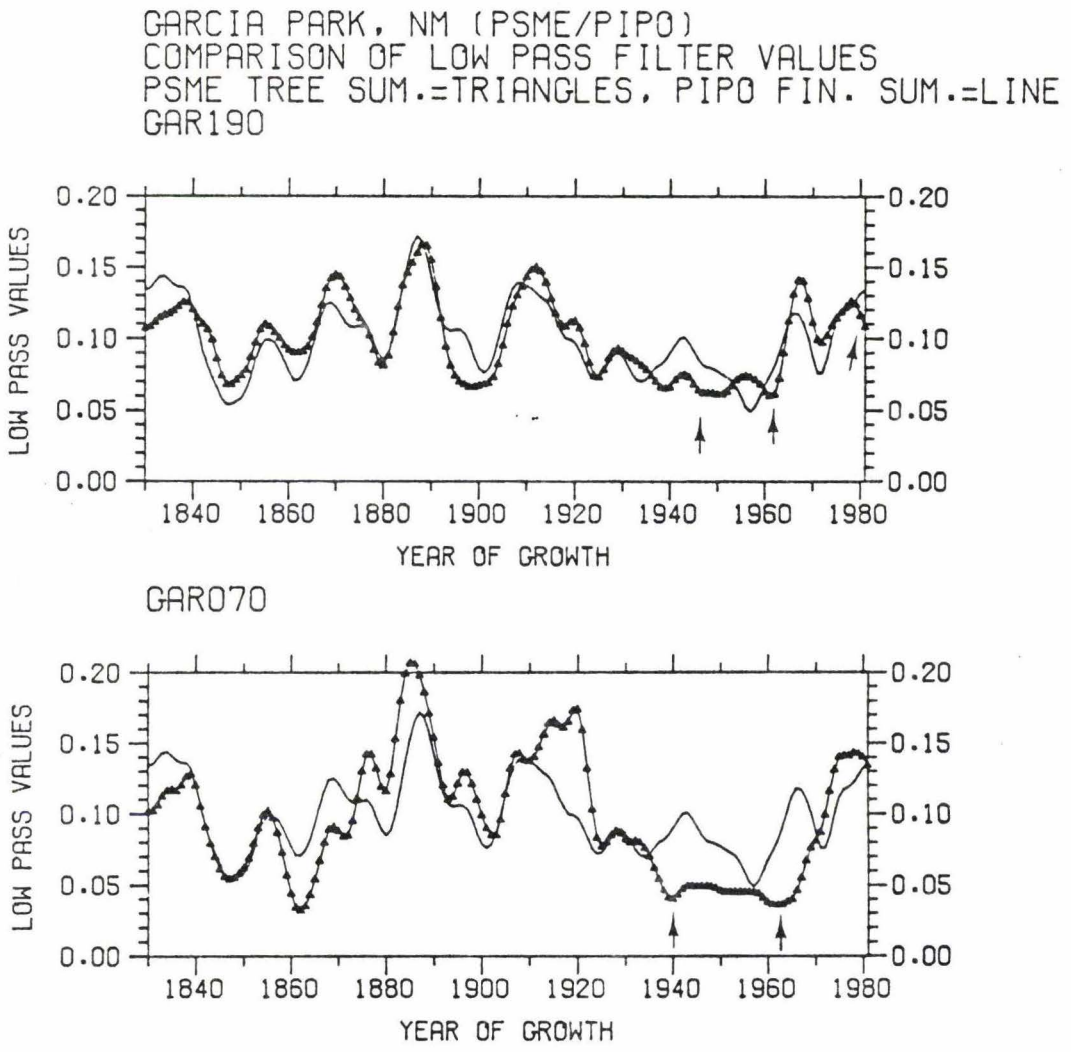


Figure 5. Plots of low pass filtered values of selected Douglas-fir trees and the ponderosa pine final summary from Garcia Park. Periods of low Douglas-fir growth during known infestations are shown with arrows.

cause cannot be determined at this time.

The individual tree summary for CPN210 (fig. 4) represents a case where Douglas-fir growth was significantly greater than ponderosa pine in the late 1930's. This rise in Douglas-fir growth with no corresponding rise in ponderosa pine growth was noted in several other trees. The cause of this difference is not known.

Despite these instances of unexplained differences in growth between the host and non-host trees, the comparisons show a general similarity in overall growth trends. Furthermore, the differences observed between host and non-host tree-ring series during the known infestation periods are usually the greatest differences observed in the comparisons.

As previously noted, the comparison of the final series for the CAB site showed no definite periods of growth loss coinciding with known periods of defoliation. Comparisons of the individual Douglas-fir tree summaries with the final piñon chronology for this site showed that some trees sustained growth loss during the present infestation and earlier infestations. However, the lack of consistent growth loss among a majority of the sampled trees for any of the known periods of infestation seems to indicate that either this particular site has not experienced the extent of defoliation that has occurred on the CPN and GAR sites have, or for some other reason many of the trees were able to continue growing at nearly the same rate as the piñon trees.

One possible explanation may be that since the CAB trees were, on the average, younger than trees at CPN and GAR, they may have been more able to withstand the effects of defoliation. Another possible explanation may be that the piñon and Douglas-fir trees sampled at this site were too dissimilar in response to climate or other environmental influences,

so that consistent differences between the series are obscured. In contrast to the CPN and GAR host and non-host collections, the CAB Douglas-fir and piñon collections were from areas separated by several miles, and the trees at the two sites were growing on different aspects, slopes, and soils. Additional collections of non-host trees closer to the host trees at CAB may help to resolve problems with the growth comparison at this site.

Corrected Host Tree Series

All of the individual tree summaries and final summaries from the CPN, GAR, and CAB collections were processed through the TRMCLM program. Figure 6 shows plots of corrected indices of the final summaries for the period 1800-1981 for CPN and GAR, and 1870-1981 for CAB. Seventeen trees were included in the CPN and GAR final summaries after approximately 1900, and nine trees were included in the CAB final summary after 1910. At least five trees comprise the earliest portions of all three final summaries.

Growth loss during each of the known periods of infestation is visible in the CPN and GAR series, whereas similar periods of growth loss are not apparent in the CAB series. The corrected index values for CPN tree growth during the 1940's, 1960's and 1979 to 1981 were the lowest values for the entire 1800-1981 chronology. The most recent infestation was just beginning to be recorded in the late 1970's, and the recovery period had not begun as of 1981.

The corrected indices for GAR are also low during the known periods of infestation, and the values for 1979-1981 were the lowest recorded for the entire 1800-1981 period. However, other periods during the chronology also have low values, such as a period during the late 1890's, that was also visible in the filtered comparisons (fig. 3). The low corrected index values observed during known infestations appear to be more consistent among

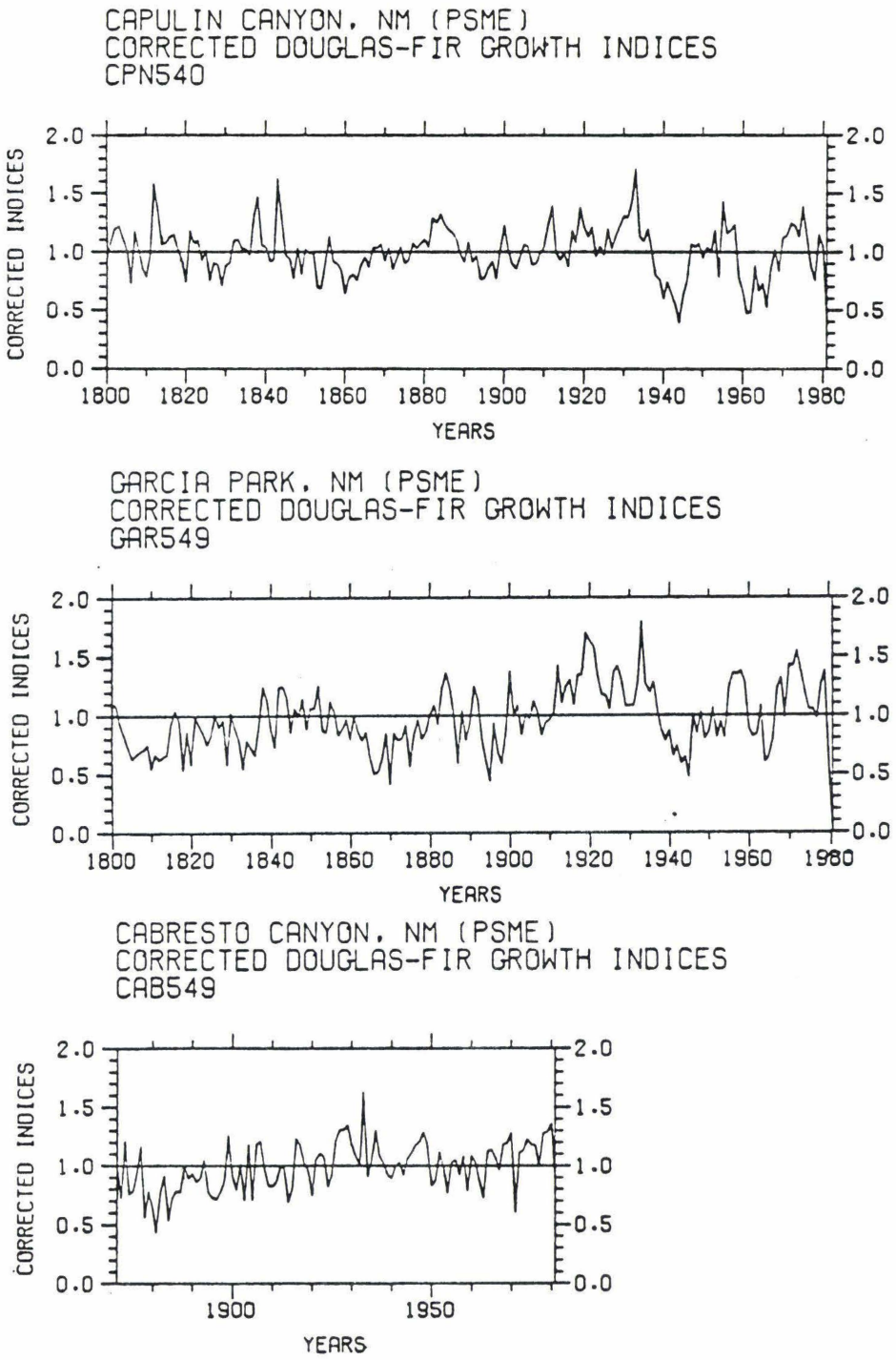


Figure 6. Plots of corrected Douglas-fir final summaries.

the sample trees than other periods of low growth.

The extended periods of low growth visible in the CPN series during known periods of WSBW outbreaks, with no comparable periods of low growth in earlier portions of the series, suggests that severe growth loss due to WSBW is a twentieth century phenomenon. This observation is less clear at the GAR site because of observed periods of low growth in earlier periods of the series. However, the growth loss during the known outbreaks at GAR also appear to be the most consistent and long lasting periods of low growth for the entire 1800-1981 period.

Measures of Growth Loss

The CAB corrected indices did not consistently show periods of growth loss that can be attributed to WSBW, so no measures of growth loss were compiled for the sample trees from this site. Measures of growth loss were compiled for each corrected index tree summary from the CPN and GAR sites, and are displayed as histograms in figures 7 and 8. The dates of infestation are approximate and are based on Forest Service records. Median values are shown on each histogram.

The maximum growth loss for one year during each of the known infestation periods was generally greater than 50 percent. In other words, tree growth was reduced to at least half of the expected growth during the lowest growth year.

The five year growth loss was at least 30 to 40 percent for most trees, but this measurement was more variable among the trees than the measurement of maximum growth loss for one year. The five year growth loss measurements for the most recent infestation (1974 to present) were not centered on the minimum corrected index values because these values were usually the last ring of the series (1981), so the five year periods included the years

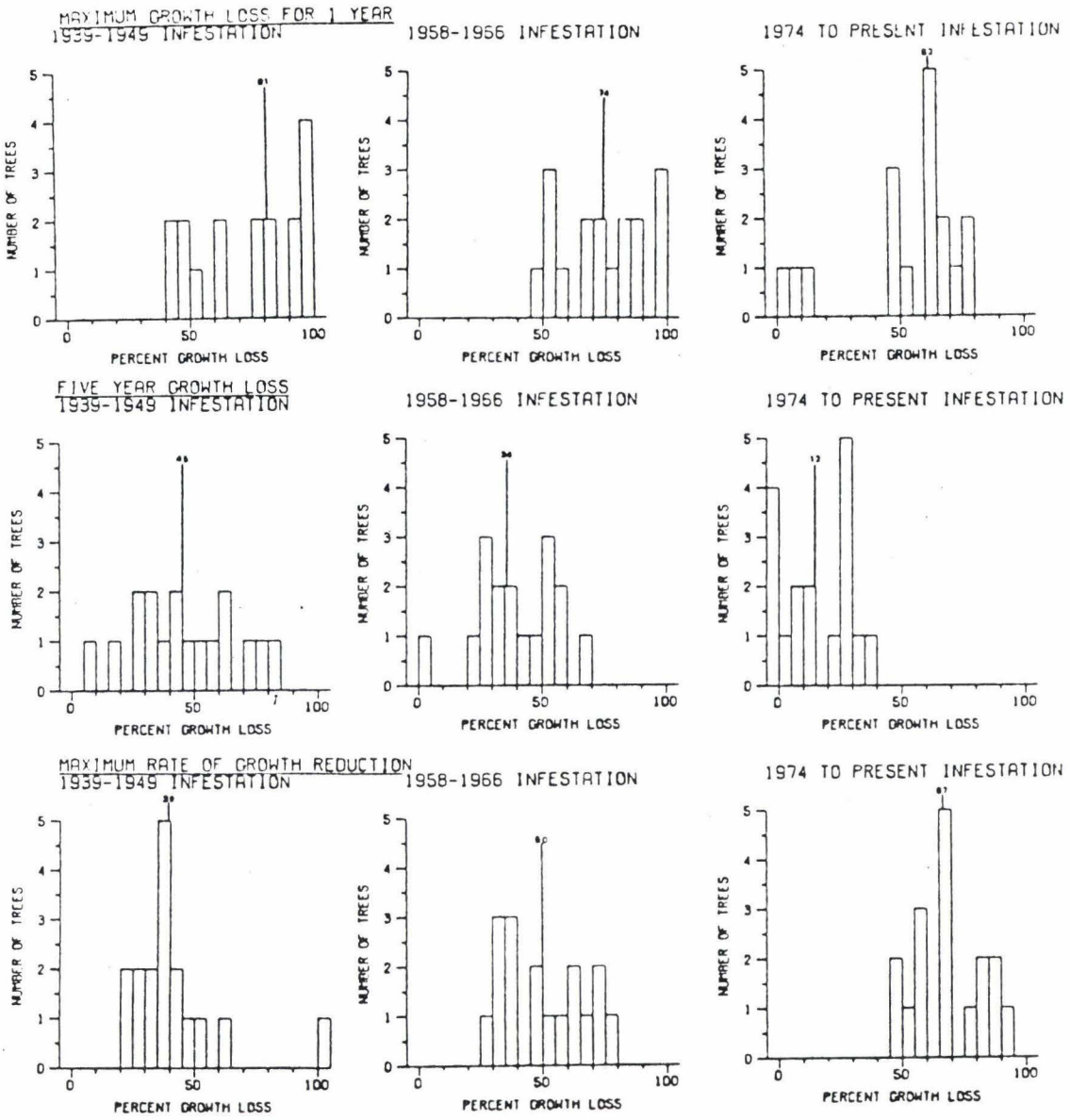


Figure 7. Histograms of growth loss measurements from Capulin Canyon. The top row is the maximum growth loss for 1 year during each known infestation period. The middle row is the average five year growth loss for each period, and the bottom row is the maximum rate of growth reduction for each period. The median growth loss values are indicated with a verticle line on each histogram.

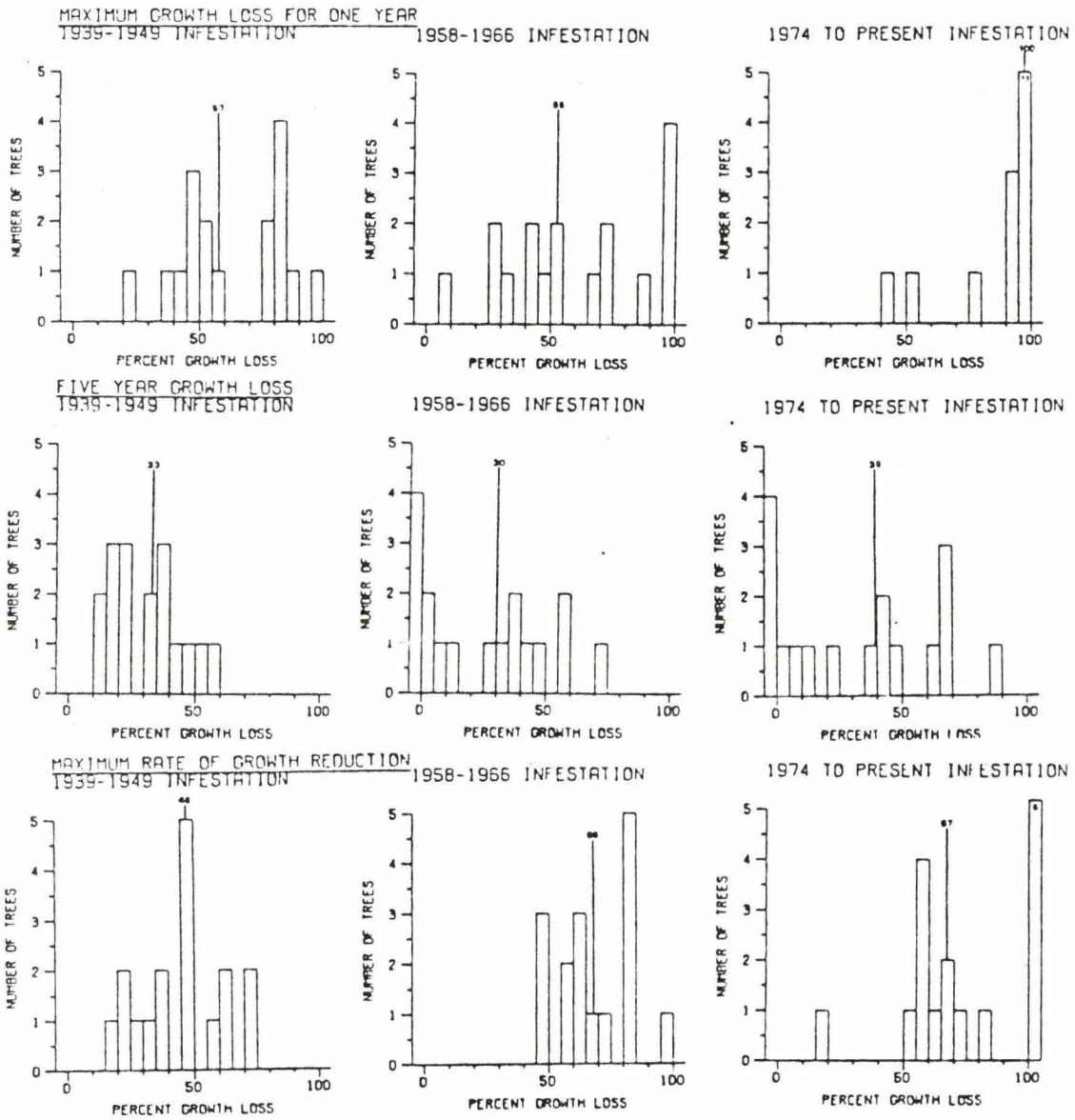


Figure 8. Histograms of growth loss measurements from Garcia Park. The top row is the maximum growth loss for 1 year during each known infestation period. The middle row is the average five year growth loss for each period, and the bottom row is the maximum rate of growth reduction for each period. The median growth loss values are indicated with a verticle line on each histogram.

1977 to 1981. Since the trees had not begun recovering by 1981, this measurement is a conservative estimate of growth loss for this outbreak.

The maximum rates of growth reduction were generally greater than 50 percent for most trees and were as high as 100 percent for some trees. It was also noted that the maximum reduction in growth from one year to the next usually occurred near the beginning of the infestation period.

SUMMARY

The comparisons of filtered host and non-host tree-ring series clearly identified three periods of low growth in the CPN and GAR host trees that corresponded with known periods of WSBW outbreaks. This evidence provided a basis for further analyses that utilized the non-host series to remove growth effects other than WSBW from the host series. The corrected host tree indices were then used to measure growth loss during identified WSBW outbreak periods.

The maximum growth loss during a single year of the outbreaks was usually greater than 50 percent. Average growth loss during five year periods was approximately 30 to 40 percent. The maximum growth loss from one year to the next was generally greater than 50 percent and was as high as 100 percent.

The measures of growth loss at the CPN site may overestimate growth loss because the ponderosa pine trees may have benefitted from defoliation of the host trees. This effect has probably not occurred at the GAR and CAB sites because the host and non-host trees are separate at these sites.

In general, the measures of growth loss are probably conservative, at least at the GAR site, because all of the measurements were from increment cores sampled at the bole of the trees. Other researchers have found

that maximum growth loss in WSBW infested trees usually occurs within the crown portion of the stem (Mott et al. 1957).

Results of comparisons of host and non-host tree-ring series at the CAB site were inconclusive. A few of the trees exhibited growth loss during present and past infestations, but most did not. Additional sampling at this site might help to determine the reasons for these results.

FUTURE WORK

We feel that additional sampling of infested trees and analysis of their tree-ring series would help to verify the findings of this study and answer other questions regarding WSBW effects on tree growth. The number of samples included in the analysis of each site is relatively small and additional sampling in these areas would probably improve the growth loss estimates.

Additional work that we would like to undertake, depending on continuous funding, includes the following:

1. The processing and analyses of increment core samples obtained in 1982 from Osha Mountain on the Taos Ranger District and Burned Mountain on the Tres Piedras Ranger District.
2. The collection of increment cores and development of a chronology for non-host trees from the Burned Mountain area.
3. The improvement of growth loss estimates for the CPN, GAR, and CAB sites by the collection and analysis of additional increment core samples.
4. The identification of possible differences in growth loss between age classes of trees or site classes.
5. The investigation of the effects of past spraying programs on radial growth of WSBW infested trees.

We plan on developing a detailed proposal describing these investigations in the near future.

ACKNOWLEDGMENTS

This study has been funded by the Forest Service Southwestern Region and CANUSA (Canada United States Spruce Budworm Program), Contract number OM 43-8371-3-425. Marvin A. Stokes supervised this study, and Marna Ares Thompson has provided valuable assistance and advice. Other individuals that assisted in field collections, crossdating, measuring, computer processing, and editing the manuscript, include Elaine Kennedy Sutherland, Terry Mazany, Thomas P. Harlan, and Richard L. Holmes.

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APPENDIX E

Pole and sawtimber top-kill damages for blocks 1 through 12, 13 through 16, and 17

TABLE 11.--Host tree species per acre vs. plot number for apparent top-kill damages to pole timber, blocks, 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WORD, CARS N.F. 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) RUNSTREAM FOR TJR
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = AT APPARENT KILL
BY V10 TREE CATAGORY VALUE = POLE POLE TIMBER
* PAGE 1 OF 2

V4	V2	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	ROW TOTAL
DF	COUNT	8	22	5	4	1	4	30	9	24	10	193
DOUGLAS FIR	ROW PCT	4.7	11.4	2.6	2.1	.5	2.1	15.5	4.7	12.4	5.2	74.8
	COL PCT	45.0	91.7	41.7	66.7	100.0	57.1	96.8	100.0	100.0	66.7	
	TOT PCT	3.5	8.5	1.9	1.6	.4	1.6	11.6	3.5	9.3	3.9	
SP	COUNT	1	0	5	2	0	0	0	0	0	0	34
SPRUCE	ROW PCT	2.9	.0	14.7	5.9	.0	.0	.0	.0	.0	.0	13.2
	COL PCT	5.0	.0	41.7	33.3	.0	.0	.0	.0	.0	.0	
	TOT PCT	.4	.0	1.9	.8	.0	.0	.0	.0	.0	.0	
WF	COUNT	10	2	2	0	0	3	1	0	0	5	31
WHITE FIR	ROW PCT	32.3	6.5	6.5	.0	.0	9.7	3.2	.0	.0	16.1	12.0
	COL PCT	50.0	8.3	16.7	.0	.0	42.9	3.2	.0	.0	33.3	
	TOT PCT	3.9	.8	.8	.0	.0	1.2	.4	.0	.0	1.9	
COLUMN TOTAL		20	24	12	6	1	7	31	9	24	15	258
		7.8	9.3	4.7	2.3	.4	2.7	12.0	3.5	9.3	5.8	100.0

(CONTINUED)

TABLE 11.--Host tree species per acre vs. plot number for apparent top-kill damages to pole timber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico--Continued

SPSS FORMAT FOR WSBW.CARSON NF 01/30/94

FILE SPSS (CREATION DATE = 01/30/94) DOWNSTREAM FOR TJR
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * * *

V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = AT APPARENT KILL
BY V10 TREE CATAGORY VALUE = POLE POLE TIMBER

* PAGE 2 OF 2

	V2			
	COUNT I			
	ROW PCT I			ROW
	COL PCT I			TOTAL
	TOT PCT I	11.I	12.I	
V4	---------I	---------I	---------I	
DF	I	23 I	47 I	193
DOUGLAS FIR	I	14.5 I	24.4 I	74.8
	I	68.3 I	69.1 I	
	I	10.9 I	18.2 I	
	-I	----- --I	---------I	
SP	I	7 I	19 I	34
SPRUCE	I	20.6 I	55.9 I	13.2
	I	17.1 I	27.9 I	
	I	2.7 I	7.4 I	
	-I	---------I	---------I	
WF	I	9 I	2 I	31
WHITE FIR	I	19.4 I	6.5 I	12.0
	I	14.6 I	2.9 I	
	I	2.3 I	.8 I	
	-I	---------I	---------I	
COLUMN		41	68	258
TOTAL		15.9	26.4	100.0

TABLE 12.--Host tree species per acre vs. plot for confirmed top-kill damages to pole timber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW,CARSON NF 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) RUNSTREAM FOR TJR
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * * *

V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = CT CONFIRMED KILL
BY V10 TREE CATAGORY VALUE = POLE POLE TIMBER

* * * * * * * * * * * * * * * * * * * \

TABLE 12.--Host tree species per acre vs. plot for confirmed top-kill damages to pole timber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico--Continued

SPSS FORMAT FOR WSBW.CARSON NF 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) RUNSTREAM FOR TJP
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = CT CONFIRMED KILL
BY V10 TREE CATAGORY VALUE = POLE POLE TIMBER
* PAGE 2 OF 2

V4	COUNT / ROW PCT / COL PCT / TOT PCT	V2 11.	V2 12.	ROW TOTAL
DF		25	12	164
DOUGLAS FIR		15.2	7.3	58.6
		67.5	75.0	
		8.9	4.3	
SP		6	4	42
SPRUCE		14.3	9.5	15.0
		16.2	25.0	
		2.1	1.4	
WF		6	0	74
WHITE FIR		8.1	.0	26.4
		16.2	.0	
		2.1	.0	
COLUMN TOTAL		37 13.2	16 5.7	280 100.0

TABLE 13.--Host tree species per acre vs. plot number for apparent top-kill damages to sawtimber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW,CARSON NF 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) UNSTREAM FOR TJR
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = AT APPARENT KILL
BY V10 TREE CATAGORY VALUE = SAWT SAW TIMBER
* PAGE 1 OF 2

V4	V2	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	ROW TOTAL
DF	COUNT	2	8	2	0	1	3	8	9	8	1	61
DOUGLAS FIR	ROW PCT	3.3	13.1	3.3	.0	1.6	4.9	13.1	14.8	13.1	1.6	66.3
	COL PCT	33.3	72.7	66.7	.0	50.0	50.0	88.9	75.0	88.9	100.0	
	TOT PCT	2.2	8.7	2.2	.0	1.1	3.3	8.7	9.8	8.7	1.1	
SP	COUNT	0	0	1	1	0	0	0	0	0	0	9
SPRUCE	ROW PCT	.0	.0	11.1	11.1	.0	.0	.0	.0	.0	.0	9.8
	COL PCT	.0	.0	33.3	100.0	.0	.0	.0	.0	.0	.0	
	TOT PCT	.0	.0	1.1	1.1	.0	.0	.0	.0	.0	.0	
WF	COUNT	4	3	0	0	1	3	1	3	1	0	22
WHITE FIR	ROW PCT	18.2	13.6	.0	.0	4.5	13.6	4.5	13.6	4.5	.0	23.9
	COL PCT	66.7	27.3	.0	.0	50.0	50.0	11.1	25.0	11.1	.0	
	TOT PCT	4.3	3.3	.0	.0	1.1	3.3	1.1	3.3	1.1	.0	
COLUMN TOTAL		6 6.5	11 12.0	3 3.3	1 1.1	2 2.2	6 6.5	9 9.8	12 13.0	9 9.8	1 1.1	92 100.0

(CONTINUED)

TABLE 13.--Host tree species per acre vs. plot number for apparent top-kill damages to sawtimber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico--Continued

SPSS FORMAT FOR WSBW,CARSON F 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) RUNSTREAM FOR TJS
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* C R O S S T A B U L A T I O N O F *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = AT APPARENT KILL
BY V10 TREE CATAGORY VALUE = SAWT SAW TIMBER
* PAGE 2 OF 2

	V2			
	COUNT			
	ROW PCT			ROW
	COL PCT			TOTAL
	TOT PCT	11.	12.	
V4				
DF	7	12	61	
DOUGLAS FIR	11.5	19.7	66.3	
	46.7	70.6		
	7.6	13.0		
SP	4	3	9	
SPRUCE	44.4	33.3	9.8	
	26.7	17.6		
	4.3	3.3		
WF	4	2	22	
WHITE FIR	18.2	9.1	23.9	
	26.7	11.8		
	4.3	2.2		
COLUMN TOTAL	15 16.3	17 18.5	92 100.0	

TABLE 14.--Host species per acre vs. plot number for confirmed top-kill damages to sawtimber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW.CARS N ..F 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) DOWNSTREAM FOR TJR
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = CT CONFIRMED KILL
BY V10 TREE CATAGORY VALUE = SAWT SAW TIMBER
* PAGE 1 OF 2

V4	V2	1.	2.	3.	4.	5.	6.	7.	8.	10.	11.	ROW TOTAL
DF	COUNT		3	3	8	14	8	1	9	3	7	59
DOUGLAS FIR	ROW PCT	3.4	5.1	5.1	13.6	23.7	13.6	1.7	15.3	5.1	11.9	59.6
	COL PCT	20.0	60.0	37.5	50.0	82.4	88.9	50.0	60.0	37.5	87.5	
	TOT PCT	2.0	3.0	3.0	8.1	14.1	8.1	1.0	9.1	3.0	7.1	
SP	COUNT		0	4	8	0	0	0	0	1	0	13
SPRUCE	ROW PCT	.0	.0	30.8	61.5	.0	.0	.0	.0	7.7	.0	13.1
	COL PCT	.0	.0	50.0	50.0	.0	.0	.0	.0	12.5	.0	
	TOT PCT	.0	.0	4.0	8.1	.0	.0	.0	.0	1.0	.0	
WF	COUNT		2	1	0	3	1	1	6	4	1	27
WHITE FIR	ROW PCT	29.6	7.4	3.7	.0	11.1	3.7	3.7	22.2	14.8	3.7	27.3
	COL PCT	80.0	40.0	12.5	.0	17.6	11.1	50.0	40.0	50.0	12.5	
	TOT PCT	8.1	2.0	1.0	.0	3.0	1.0	1.0	6.1	4.0	1.0	
COLUMN TOTAL		10 / 10.1	5 / 5.1	8 / 8.1	16 / 16.2	17 / 17.2	9 / 9.1	2 / 2.0	15 / 15.2	8 / 8.1	8 / 8.1	99 / 100.0

(CONTINUED)

TABLE 14.--Host species per acre vs. plot number for confirmed top-kill damages to sawtimber, blocks 1 through 12. WSBW damage assessment project, Carson National Forest, New Mexico--Continued

SPSS FORMAT FOR WSBW.CARSON NF 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) RUNSTREAM FOR TJR
SUBFILE SPS1 SPS2 SPS3 SPS4 SPS5 SPS6 SPS7 SPS8 SPS9 SP10
SP11 SP12

* * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = CT CONFIRMED KILL
BY V10 TREE CATAGORY VALUE = SAWT SAW TIMBER
* PAGE 2 OF 2

V4	V2 COUNT / ROW PCT / COL PCT / TOT PCT	12.	ROW TOTAL
DF DOUGLAS FIR		1 1.7 100.0 1.0	59 59.6
SP SPRUCE		0 .0 .0 .0	13 13.1
WF WHITE FIR		0 .0 .0 .0	27 27.3
COLUMN TOTAL		1 1.0	99 100.0

TABLE 15.--Host tree species per acre vs. plot number for apparent top-kill damages to pole timber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

VA / BY VB / TOT PCT	13.	14.	15.	16.	TOTAL
DF	74	70	6	1	93
DOUGLAS FIR	81.7	70.8	6.5	1.1	58.6
	94.2	72.3	30.0	3.4	
	47.2	44.3	3.8	.6	
SP	4	2	11	20	34
SPRUCE	11.8	5.9	32.4	58.8	21.4
	1.9	6.5	55.0	69.0	
	.6	1.3	6.9	12.6	
TF	3	0	0	8	9
TRUE FIR	33.3	.0	.0	100.0	5.0
	1.4	.0	.0	27.6	
	.6	.0	.0	5.0	
WF	2	19	3	0	24
WHITE FIR	8.3	79.2	12.5	.0	15.1
	2.8	61.3	15.0	.0	
	1.3	11.9	1.9	.0	
COLUMN TOTAL	73	91	20	29	159
	49.7	19.5	12.6	18.2	100.0

TABLE 16.--Host tree species per acre vs. plot number for confirmed top-kill damages to pole timber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW.CARSON .F 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) DOWNSTREAM FOR TOP
SUBFILE SP13 SP14 SP15 SP16

* * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = CT CONFIRMED KILL
BY V10 TREE CATAGORY VALUE = POLE POLE TIMBER
* PAGE 1 OF 1

	V2		
	COUNT I		
	ROW PCT I		ROW
	COL PCT I		TOTAL
	TOT PCT I	13.I	
V4	--------I--------I		
DF	I	8 I	8
DOUGLAS FIR	I	100.0 I	100.0
	I	100.0 I	
	I	100.0 I	
	-I--------I		
COLUMN		8	8
TOTAL		100.0	100.0

TABLE 17.--Host tree species per acre vs. plot number for apparent top-kill damages to sawtimber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

		13.	14.	15.	16.	ROW TOTAL
VA						
DF		25	3	10	1	39
DOUGLAS FIR		64.1	7.7	25.6	2.6	70.9
		100.	27.3	71.4	20.0	
		45.5	5.5	18.2	1.8	
DF			0	2	1	3
SPRUCE		.0	.0	66.7	33.3	5.5
		.0	.0	14.3	20.0	
		.0	.0	3.6	1.8	
TF			0	0	3	3
TRUE FIR		.0	.0	.0	100.0	5.5
		.0	.0	.0	60.0	
		.0	.0	.0	5.5	
WF			8	2	0	10
WHITE FIR		.0	80.0	20.0	.0	18.2
		.0	72.7	14.3	.0	
		.0	14.5	3.6	.0	
COLUMN TOTAL		25	11	14	5	55
		45.5	20.0	25.5	9.1	100.0

TABLE 18.--Host tree species vs. plot number for confirmed top-kill damages to sawtimber, blocks 13 through 16. WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW.CARSON NF 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) UNSTREAM FOR TJS
SUBFILE SP13 SP14 SP15 SP16

* * * * * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * * * * * *

V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = CT CONFIRMED KILL
BY V10 TREE CATEGORY VALUE = SAWT SAW TIMBER

* * * * * * * * * * * * * * * * * * \

TABLE 19.--Host tree species vs. plot number for apparent top-kill damages to pole timber, block 17.
WSBW damage assessment project, Carson National Forest, New Mexico

SPSS FORMAT FOR WSBW,CARSON F 01/30/84

FILE SPSS (CREATION DATE = 01/30/84) RUNSTREAM FOR TJP
SUBFILE SP17

* C R O S S T A B U L A T I O N O F *
V4 SPECIES BY V2 PLOT NUMBER
CONTROLLING FOR..
V9 TOP CONDITION VALUE = AT APPARENT KILL
BY V10 TREE CATAGORY VALUE = POLE POLE TIMBER
* PAGE 1 OF 1

	V2	
	COUNT / ROW PCT / COL PCT / TOT PCT	ROW TOTAL
V4	17.	
DF DOUGLAS FIR	1 / 100.0 / 33.3 / 33.3	1 / 33.3
SP SPRUCE	1 / 100.0 / 33.3 / 33.3	1 / 33.3
WF WHITE FIR	1 / 100.0 / 33.3 / 33.3	1 / 33.3
COLUMN TOTAL	3 / 100.0	3 / 100.0

APPENDIX F

Insect density data summaries

TABLE 20.--Average egg mass densities, WSBW damage assessment project, Carson National Forest, New Mexico, 1978-83[1]

Block	Egg masses per m^2 of foliage					
	1978	1979	1980	1981	1982	1983
1	41.1	25.2	66.8	13.4	7.1	22.9
2	11.1	34.0	72.2	20.4	36.6	20.2
3	17.0	39.5	31.8	5.9	16.0	2.0
4	34.9	35.1	50.9	25.3	17.5	13.8
5	25.1	32.8	92.7	21.2	28.9	52.2
6	13.1	36.6	89.6	18.6	34.1	62.8
7	27.3	47.6	39.3	16.6	23.1	18.8
8	24.2	33.0	72.2	16.3	14.7	19.6
9	3.6	21.5	24.4	34.1	14.6	15.9
10	21.5	40.2	78.5	13.4	24.6	42.3
11	15.2	67.9	42.5	42.2	19.7	20.2
12	13.6	39.6	43.8	56.4	56.4	15.7
Blocks 1-12 $\bar{x}$	20.6	37.6	58.7	23.7	24.4	25.5
13		25.4	32.0	20.8	16.5	24.5
14		16.5	14.3	30.6	13.8	31.2
15		0	13.7	16.6	17.6	34.5
16		3.3	5.4	24.4	5.5	21.0
Blocks 13-16 $\bar{x}$		11.3	16.4	23.1	13.4	27.8
17		0	1.8	8.5	19.0	10.8

[1] Blocks 1 through 12 were established in 1978; 13 through 16 in 1979.

TABLE 21.--Average larval densities,[1] WSBW damage assessment project, Carson National Forest, New Mexico, 1979-82[2]

Block	Larvae per 100 live buds			
	1979	1980	1981	1982
1	36.6	19.6	14.2	9.0
2	20.3	15.7	18.0	5.9
3	26.8	14.6	18.7	6.9
4	21.7	13.0	13.1	5.3
5	29.2	14.3	19.8	10.4
6	15.9	19.6	27.6	4.9
7	29.2	13.6	14.9	9.1
8	33.2	15.2	20.4	7.6
9	7.7	19.1	24.1	13.5
10	28.9	15.2	16.5	6.0
11	28.9	22.9	8.7	38.2
12	25.9	15.0	12.0	24.9
Blocks 1-12 $\bar{x}$	25.4	16.5	17.3	11.8
13	0.8	12.9	18.7	11.8
14	0.2	3.1	15.8	13.2
15	0.3	1.9	19.4	14.1
16	0.1	1.5	16.2	37.1
Blocks 13-16 $\bar{x}$	0.4	4.9	17.5	19.1
17	0.4	4.8	17.5	9.0

[1] Averages are for 10 Douglas-fir trees; 2 branches per tree.
[2] Blocks 1 through 12 established in 1978; 13 through 17 in 1979.